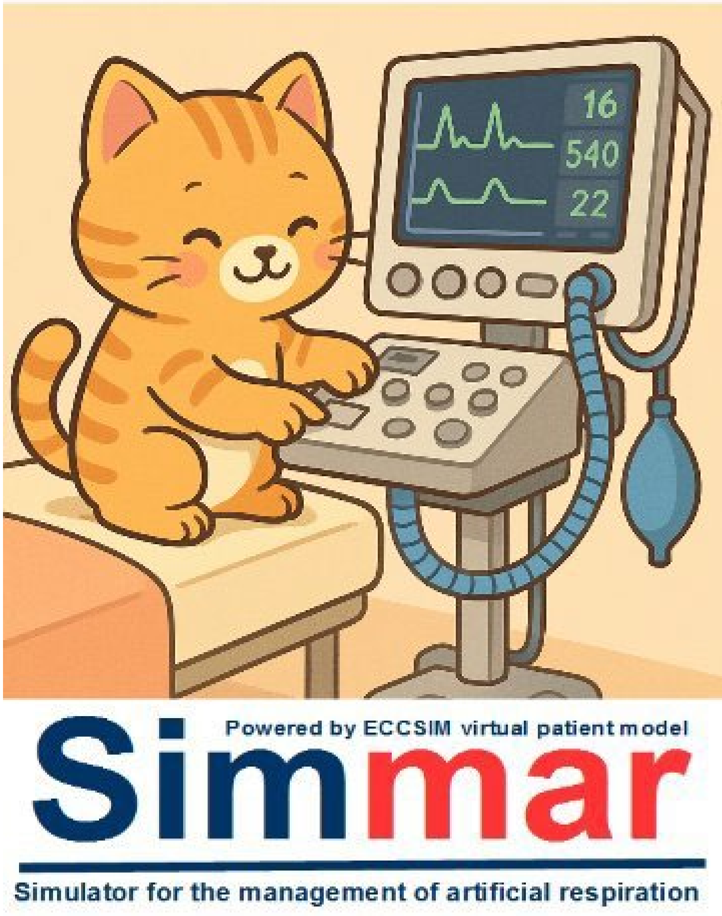
2025/03/23 for ver. 1.0.2

Simmar software for ventilatory therapy training

Operation Manual (12th Edition) for ver. 1.0.2



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Agreement with Nihon Kohden Co.
This software simulates the screen configuration and interface of the NKV-330 ventilator manufactured by Nihon Kohden quite precisely.
Permission to use this product has been granted by Nihon Kohden on condition that the following text is displayed on the label. Please be sure to read and understand it before use.

This application implements a user interface that simulates the nkv-330 with the permission of Nihon Kohden, but please note that the behavior of the application is not the same as that of the actual device. The application developer has no conflict of interest with Nihon Kohden Co.

Chapter.0 Preparing for Installation and Training

Notes on installation.

☑Please use a PC that conforms to the following recommended environment. Currently, mac PCs and iPads are not supported.
OS :Windows 7/10/11 Pro.Home 32/64bit
CPU : intel Celeron N4100 or higher
Memory : 8GB or more
Display: 1920x 1280 pixel touch panel recommended (1366x768 pixel is acceptable except for nkv-330 simulated console)

☑ Install with a user account that contains only half-width alphanumeric characters. Please note that if you use double-byte (2-byte) characters in the user account, the installer will stop with an error.
characters in the user account, the installer will stop with an error.

☑It is strongly recommended to select "Run as administrator" to start the first time.

Installation Procedure

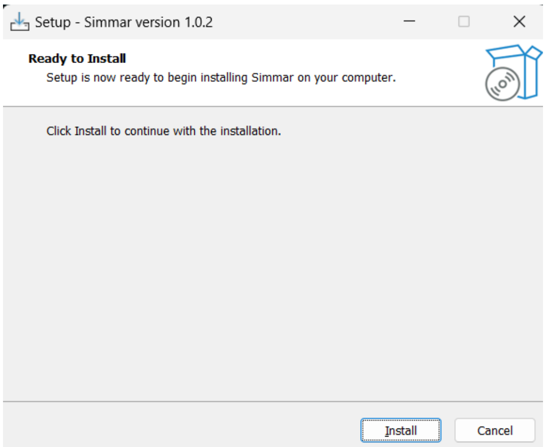
Step.1 Go to https://team-messer.github.io/Software-release/より and download the latest file (Setup_simmar_102.zip).

Step.2 Extract the zip file to an appropriate folder.
Note: If the compressed file is installed without decompression, it may not be installed correctly.

The first time you run the program, please run it with "administrator privileges". Depending on your security settings, there is a possibility that the required sub-folders may fail when they are automatically generated.

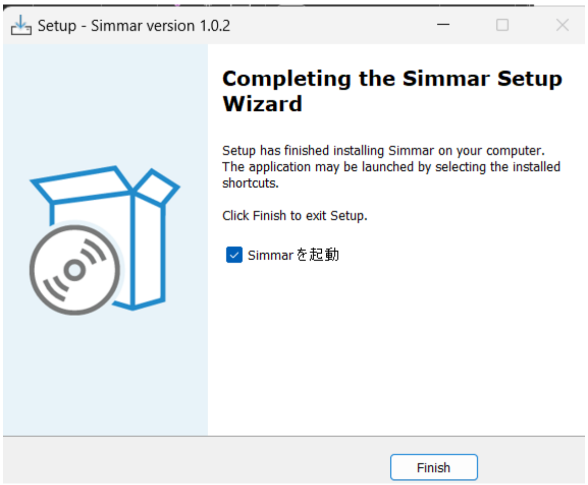
Step 3
Double-click Setup_Simmar_102.exe extracted to the desktop or other appropriate location.

Step 4



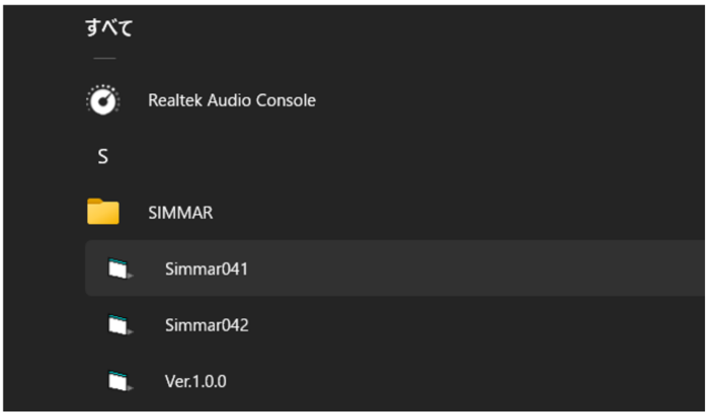
The installer will launch as shown on the left.

Step. 5



If the dialog box shown on the left appears, the installation was successful. Press "finish" to start Simmar.

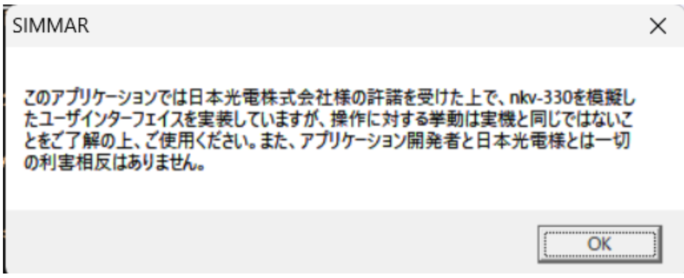
Note: Simmar applications are installed in the c:¥Simmar folder. The c:¥Simmar¥Scenario folder and c:¥Simmar¥Trend folder are automatically created when the application is launched for the first time. Depending on your security settings, automatic creation may fail. In that case, please contact your system administrator.



Step 1

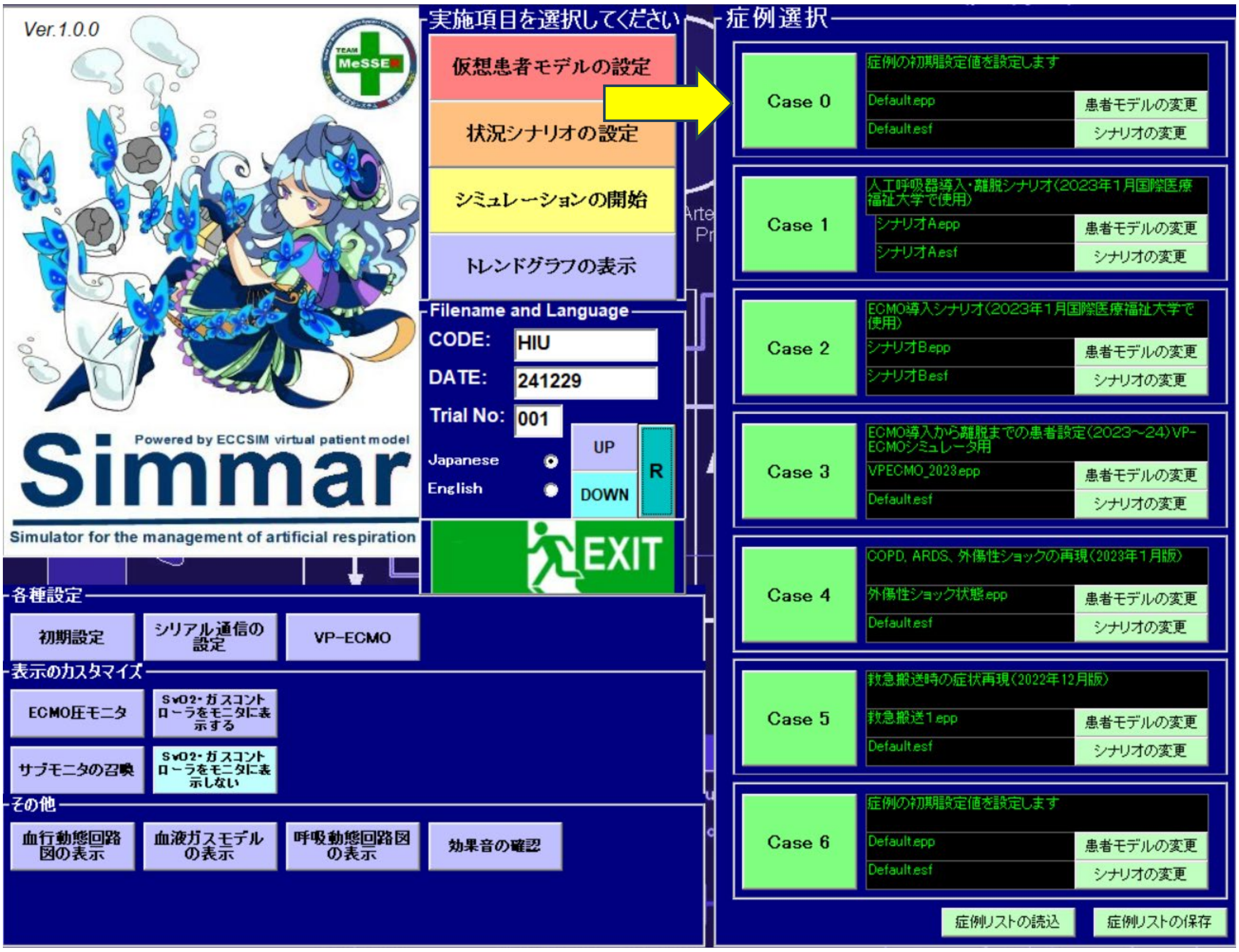
From the Start menu, select "Start" ⇒ "All" ⇒ "SIMMAR" ⇒ "Ver. 1.0.0".

(Right-click and select "Pin to Start" to specify and launch it directly from the Start menu next time.)



Step.2

Although this software imitates the screen interface of nkv-330, we have discussed this with Nihon Kohden in advance and have received permission to use the screen design under the condition that the text on the left is posted. We ask for your understanding.



Step3.

The top menu screen will appear. Select the desired case from the case selection menu on the right. This manual describes the case in which Case 0 is selected.

To exit this software, click the "EXIT" button.

Before the end of the session, the credits shown on the left will be displayed.

If your PC has multiple displays, you can display the vital signs monitor screen and the ventilator screen on separate displays.

If you want to place the screen in the same position the next time you start, check the "Save screen position information" checkbox.

The "OK" button is pressed to exit normally.

[Attention.

This simulator is designed for a 1080pixel screen, so a 768pixel screen on a portable tablet or similar device will not have enough vertical resolution for operation.

To change the vertical resolution from 1080pixel to 768pixel, press the upper right corner of the respiratory console screen.

Click on the button.

The selection menu shown on the left will appear.

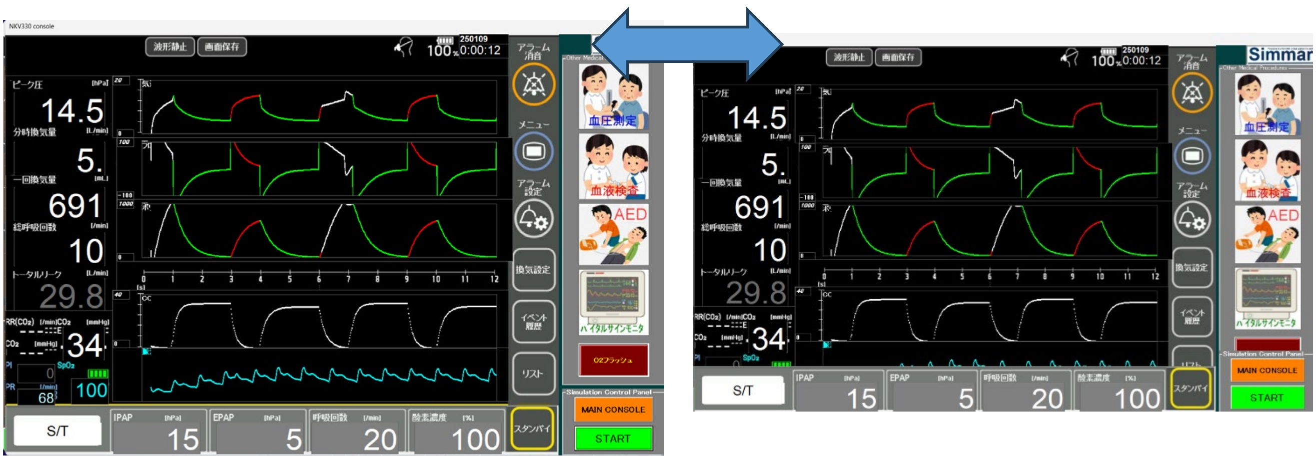
When "768 pixel vertical" is selected, the display at the bottom of the console moves up.

(In this mode, some functions and displays are restricted.)

To return to the original, select "Vertical 1080 pixel".

To return to the title screen at startup, click on "Return to Menu Screen.

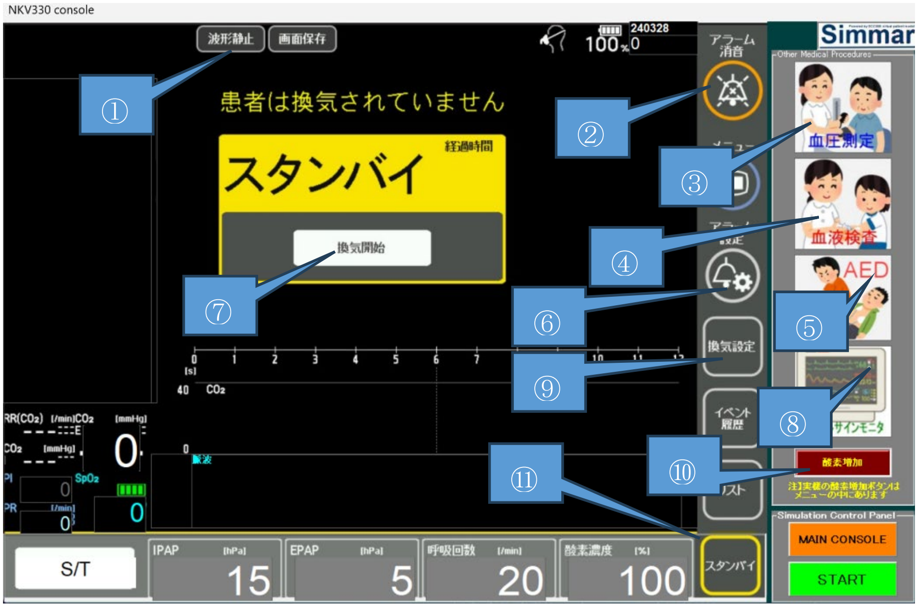
alternating switch



Vertical 1080 pixel mode　　　　Vertical 768 pixel mode

Chapter 2: Operation of Ventilator Consoles

Starting from Ver. 0.4.1, we have implemented a user interface that simulates the operation panel of nkv-330 (manufactured by Nihon Kohden). Of course, not all functions are simulated. The available functions are as follows

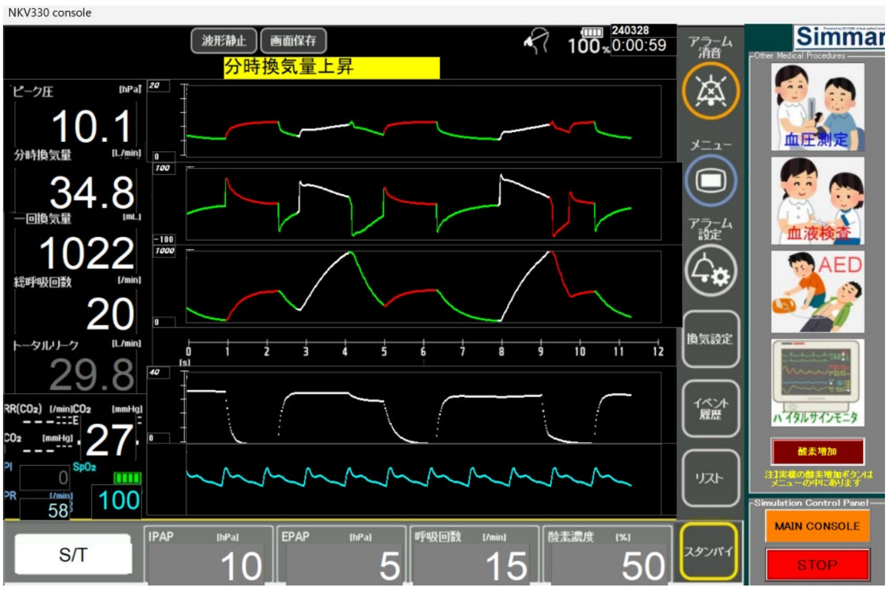


① Start of ventilation
② Stopping ventilation
③ Ventilation setting
④ Alarm Setting
⑤ Alarm silencing
⑥ waveform rest
⑦ oxygen increase
⑧ Blood pressure measurement
⑨ blood test
⑩ Automated External Defibrillator Device
⑪ Vital Signs Monitor Display

Attention.

Please note that the functions in the menu, event history, lists, and maintenance functions are not simulated.

Clicking the "START" button in the lower right corner starts the simulation, and complex operations such as checking the PV curve and interlocking operation with ECMO can be performed by selecting "MAIN CONSOLE" (see Chapter 3).



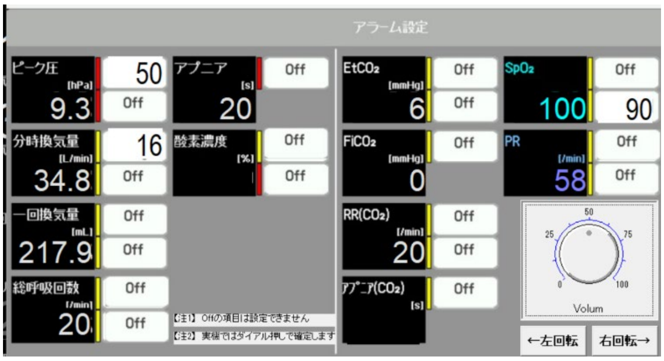
When the "Start Ventilation" button (①) is clicked, ventilation by the ventilator starts and various parameters and waveforms are displayed as shown on the left. Clicking the "Standby" button (②) stops ventilation and returns to the previous screen.

Vital signs during ventilation can be checked by "blood pressure measurement" (8), "blood test" (9), and "vital sign monitor" (11), respectively.

Note
Clicking the AED button will suddenly start defibrillation by electric shock. Do not press the button unnecessarily, as cardiac arrest, atrial fibrillation, or other arrhythmias may occur.

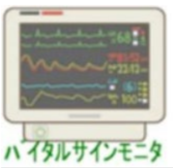
To change the ventilation settings, click on "Ventilation Settings" (③) to change them.

In the Ventilation Settings screen, SPONT-PS, S/T, PCV, PRVC, PPV, O2 Therapy can be selected. Clicking on each item brings up an input panel, so change the value using the ▼▲ buttons and click the "Set" button to set the value. <u>In the actual device, the slider and the front dial can be used to set the value, but that function is not implemented</u>. Please note that this function is not implemented.

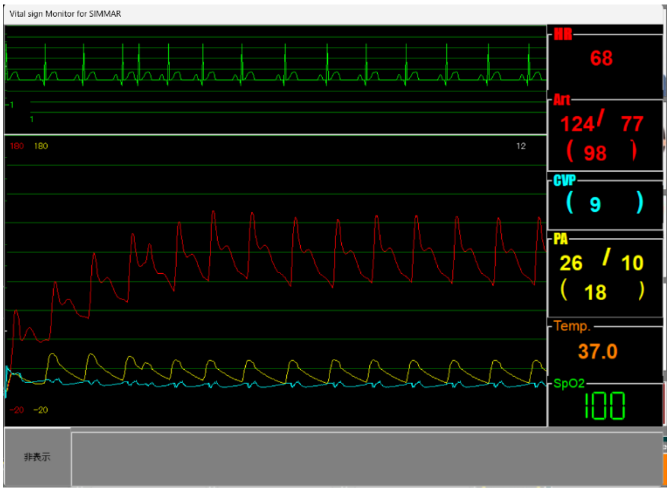


Some alarms can be set by clicking "Alarm Settings" (⑥).
Alarm settings are made with the physical dial on the front panel on the actual device, but with this software, they are made with the simulated dial on the lower right. Click on the item you wish to set and use the "Rotate Right" and "Rotate Left" buttons. <u>Since it is a simulated dial, place the mouse cursor on the dial and right-click to rotate right and left-click to rotate left</u>.

Note: In Ver. 1.0.2, items set to "Off" cannot be set (will be supported in the future).



Clicking on "Vital Signs Monitor," "Blood Pressure Measurement," or "Blood Test" will display real-time values from the circulation-metabolism simulation model running in the background.
If the vital signs monitor is resized, the display will follow the size of the next scan.
Click "Show SvO2, Gas Controller on Monitor" under "Customize Display" in the top menu to display SvO2, the gas flow controller and blender of the ECMO device as shown below. this display is useful when simulating ECMO connection conditions. For details, please refer to the "VP-ECMO01 Operation Manual".



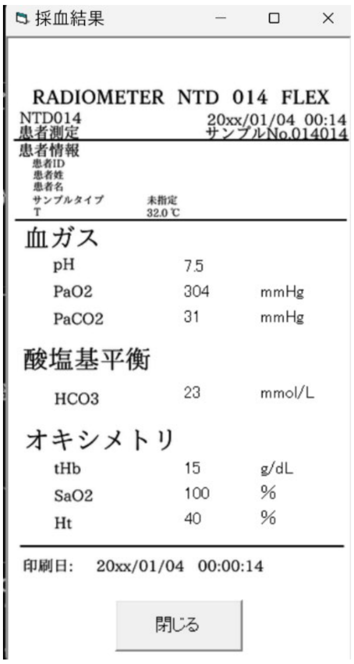
<u>Standard Vital Signs Monitor Display</u>　　　　<u>Monitor Display for ECMO Simulation</u>

Clicking on the "**Measure Blood Pressure**" button displays the maximum and minimum blood pressure and pulse rate of the virtual patient. These values change in real time based on the settings of the virtual patient model.

Clicking on the "**Blood Tests**" button will display PaO2, PaCO2, HCO3, tHb, SaO2, and Ht for the virtual patient. This display simulates the printout output of the NTD 014 (from RADIOMETER).

These values change in real time in response to ventilator operations based on the settings of the virtual patient model.

<u>Blood pressure display</u>



採血結果

RADIOMETER NTD 014 FLEX

NTD014　20xx/01/04 00:14
患者測定　サンプルNo.014014

患者情報
患者ID
患者姓
患者名
サンプルタイプ　未指定
T　32.0 ℃

血ガス		
pH	7.5	
PaO2	304	mmHg
PaCO2	31	mmHg
酸塩基平衡		
HCO3	23	mmol/L
オキシメトリ		
tHb	15	g/dL
SaO2	100	%
Ht	40	%

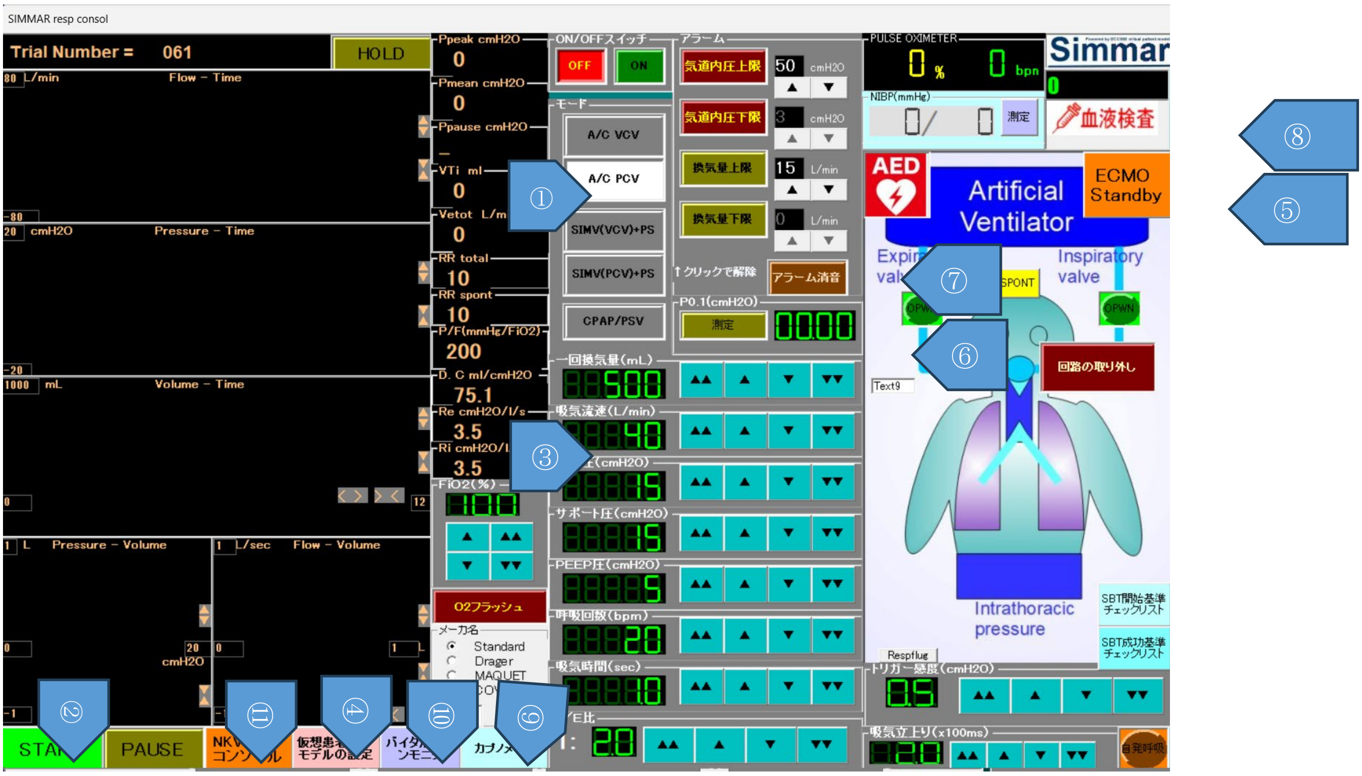
印刷日:　20xx/01/04　00:00:14

閉じる

<u>Display of blood gas information</u>

Chapter 3 Main Console Operation

Using the main console, you can operate the ventilator with the virtual patient connected, make various settings, and display detailed information not shown by the ventilator A simulation session is started by pressing the START button. The operation of each function is described below.



① Start and end the session.

② Select the mode of ventilator. You may select metered, metered-pressure, SIMV, pressure-assisted ventilation, or continuous positive pressure ventilation.

③ Respiratory parameters are set. Trigger sensitivity is set to flow trigger only.

④ Set the patient's respiratory parameters (lung compliance, airway resistance, etc.). ⇒ Go to Chapter 3.

⑤ Switch to respiratory console display simulating NKV330

⑥ The vital signs monitor used in the ICU is displayed on a separate screen.

⑦ The capnometer screen appears.

⑧ Display of circulation and blood gas information. Pressing the "Blood Test" button displays blood test results. Pressing the "Measure" button displays the maximum and minimum blood pressure.

⑨ During simulation in ventilatory mode, the upper and lower limit alarms for airway pressure and minute ventilation volume work. To silence the alarms, click on the appropriate alarm. The alarm sounds only during the time the relevant event is occurring.

⑩ Measure P0.1 (change in airway pressure at 100 ms occlusion after the start of inspiration) as an index of effort breathing.

⑪ If ECMO is used in conjunction with ECMO, the ECMO device appears by pressing this button.

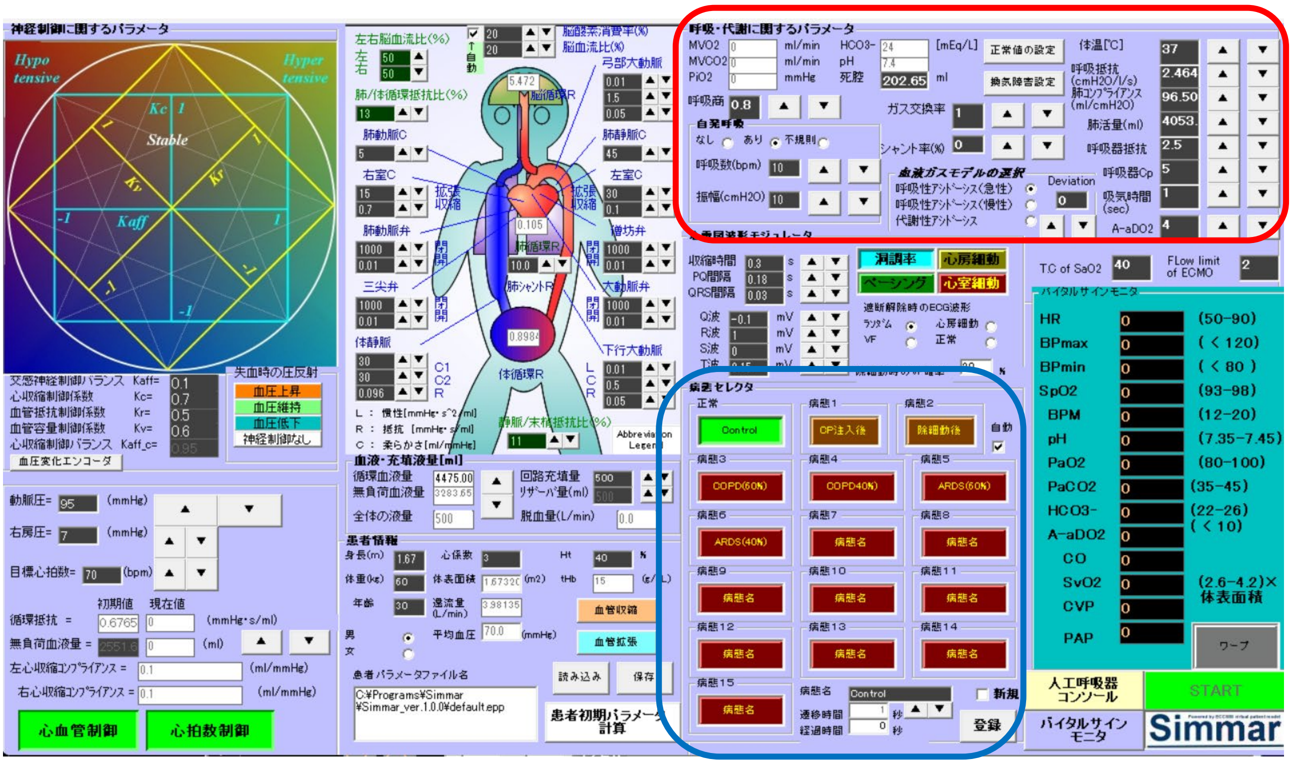
The upper cutoff limit of P0.1 is 3.5～ 4.0 cmH2O, and the lower cutoff limit is 1.1 cmH2O. or too weak inspiratory effort can be detected with high accuracy.

References: Shin-ichiro Ohshita, Respiratory management in coronary disaster ― P-SILI prevention and non-invasive lung mechanics evaluation by P 0.1― ,Medtronic Professional Quest Vol.39,2020

Chapter 4: Operation of the Patient Model Setup Panel

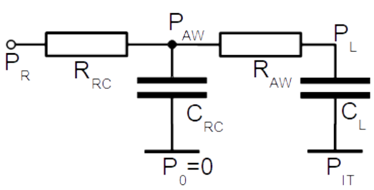
Because it uses the patient model of ECCSIM, a virtual patient simulator for extracorporeal circulation education, the software includes parameters of circulatory dynamics and its autonomic control, modulators of ECG waveforms, etc.

The parameters related to respiration and metabolism are shown in the red frame in the figure below. The parameters indicated by white letters on a black background can be changed during the simulation.



(1) Ventilatory dynamic parameters of the lung and ventilatory circuit

As a ventilation dynamic model, we use the simple concentrated constant circuit shown on the left. The respective circuit symbols and names are as follows



P_R: Respiratory airway pressure　　P_{AW}: Airway pressure

P_L: intrapulmonary pressure　　P_{IT}: Intrathoracic pressure

$R_{(RC)}$: Respiratory circuit resistance　　$R_{(AW)}$: Airway resistance

C_{RC}: Respiratory circuit compliance　　C_L : Lung compliance

Click the "Calculate Normal Value" button to set the normal value (estimated value) using the following formula.

Airway resistance (male)　　$R_{AW} = 7.2 - 0.002 \times age - 0.028 \times height$ (cm)

(Female)　　$R_{AW} = 6.03 - 0.003 \times age - 0.019 \times height$ (cm)

Lung capacity (male)　　: $Vc = (27.63 - 0.112 \times age) \times height$ (cm)

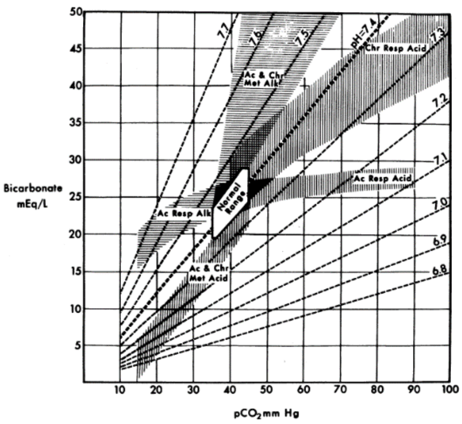
(Female)　　$Vc = (21.78 - 0.101 \times age) \times height$ (cm)

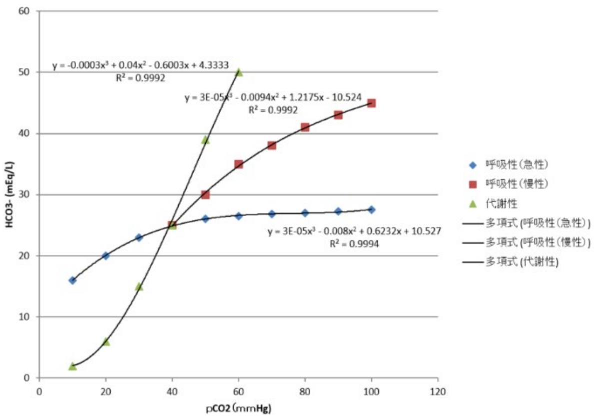
single ventilation　　$V_T = Vc \div 6.0$　　Lung compliance　　$C_L = V_{(T)} \div 7.0$

You may want to set normal values for each and, depending on the expected pathophysiology, increase airway resistance for obstructive ventilatory disorders and decrease lung compliance for restrictive ventilatory disorders.

(2) About the acid-base equilibrium model

To reproduce blood gas changes in respiratory and metabolic acidosis, an acid-base equilibrium model using the Significance band is employed. From the $PaCO_2$ value determined by ventilation, the value of HCO_3^- is determined by applying the Significance band approximation formula shown in the figure belov





1) Gerald S. Arbuset.al, An in vivo acid-base nomogram for clinical use, CMA J./August 18,pp.291-2,1970

(3) About the pathological selector

Using the area circled in blue, you can save the biological parameters you have set and reproduce them at any time during the simulation. Please turn on the button for the appropriate condition number, set the parameters for various conditions, enter the condition name, and press the Register button. The next time you press the button, the condition will be reproduced. When the button for the condition number is turned ON, the previously registered condition is automatically set. To set a new condition based on the current condition, ☑ "New" above the registration button.

(4) About Spontaneous Breathing

Set the maximum value of intrathoracic pressure P_{IT} and respiratory rate, and select "with spontaneous respiration" to initiate spontaneous respiration in the simulation. Selecting "Irregular" changes the respiratory interval within the set value± 50% of the respiratory cycle determined by the respiratory rate.

(5) Setting and saving patient parameters

By entering the height, weight, age, heart coefficient (usually about 3), and Ht of the virtual patient, and clicking on "Calculate Initial Patient Parameters," you can set representative values for the patient's circulating blood volume, vascular resistance, compliance, airway resistance, and lung

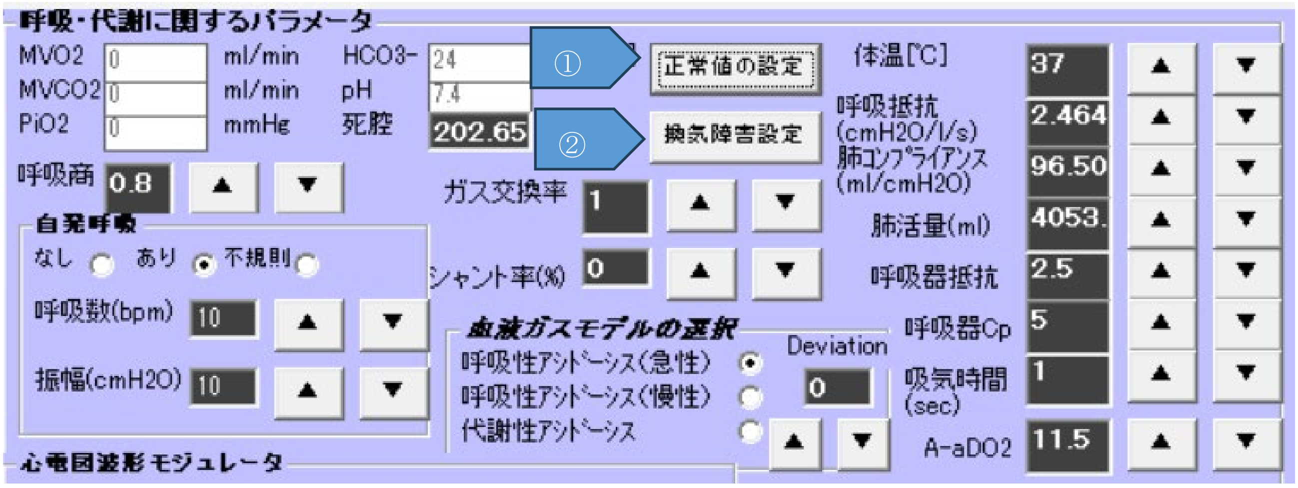
compliance.

Please note that the set representative values are only valid after clicking the "Register" button.

Click the Save button to save all configuration information in the Virtual Patient Settings panel under any file name. Click the Load button and specify a file name to recreate the previous settings. The configuration file will be saved in the following directory

C:\Program files(x86)\Simmar

(6) How to set up blood gas parameters for a hypothetical patient, ″Setting up a ventilatory disturbance″



After setting patient parameters, click the ″Set Normal Values″ (①) button in the ″Respiratory and Metabolic Parameters″ setting form to set normal values (representative values) for respiratory-related parameters. The values to be set are,

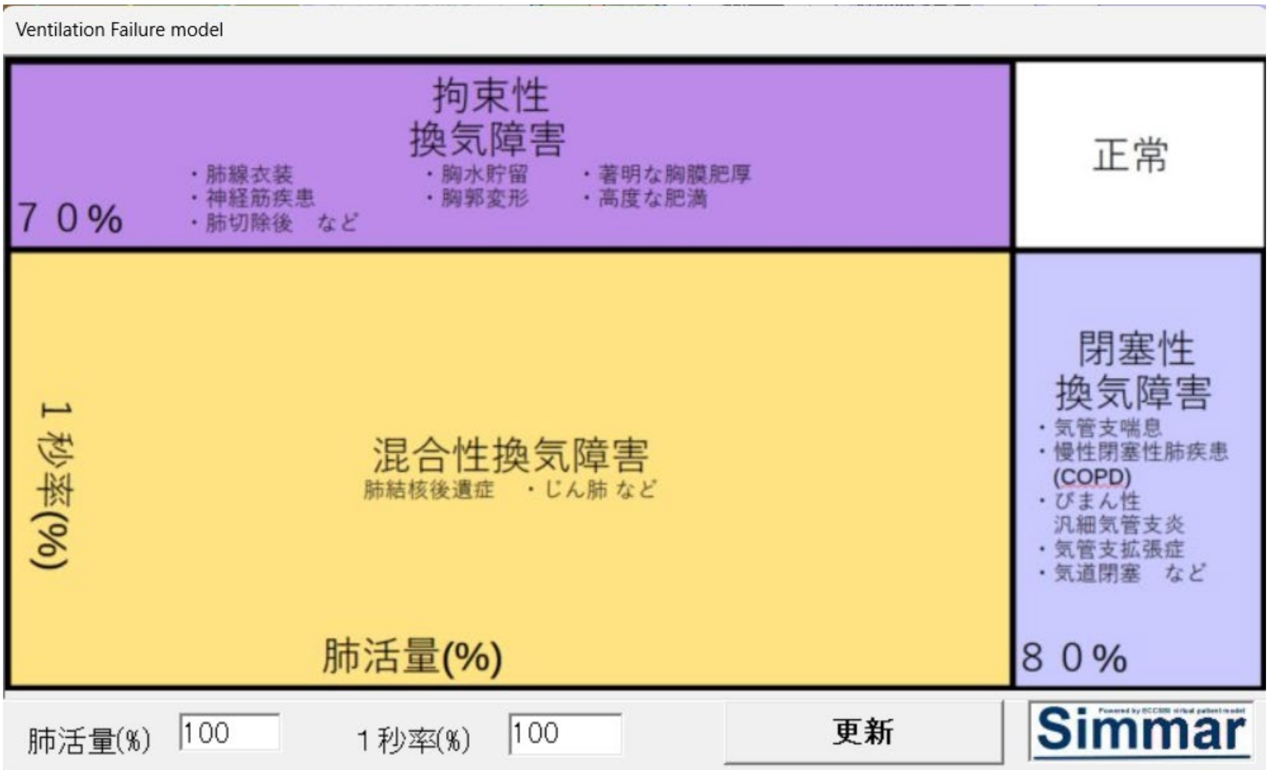
The five items are respiratory resistance, lung capacity, static lung compliance, Aa-DO2, and physiological dead space VD.

A-aDO2 and VD are calculated by the following equation.

$$A\text{-}aDO2 = 4 + age/4$$

$$VD = VC \times 0.05\ (mL)$$

The ventilation disturbance can be set by clicking on the "Ventilation Disturbance Settings" button to set parameters from %VC and %FEV.



By clicking on the classification chart of ventilation disorders above, static lung compliance Cs and airway resistance Raw are calculated from the representative value of lung capacity under normal conditions, VC0, using the following formulas, respectively.

Numerical model of ventilation impairment

When % lung capacity Vc% is given

$$V_C = \frac{V_{C0} \cdot V_C\%}{100} (ml)$$

The static lung compliance estimate C_S is,

$$C_S = \frac{V_C}{42} (ml / cmH_2O)$$

When 1 second rate $FEV_1\%$ is given

If lung compliance is C_S and airway resistance is R_{AW}, the time constant of the decay curve of lung air volume is $C_S \cdot R_{AW}$ because

The called lung air volume $V_E(t)$ is,

$$V_E(t) = V_C\left(1 - e^{-\frac{t}{C_S R_{AW}}}\right)$$

Namely,

$$\frac{FEV_1\%}{100} = \frac{V_E(1)}{V_C} = 1 - e^{-\frac{1}{C_S R_{AW}}}$$

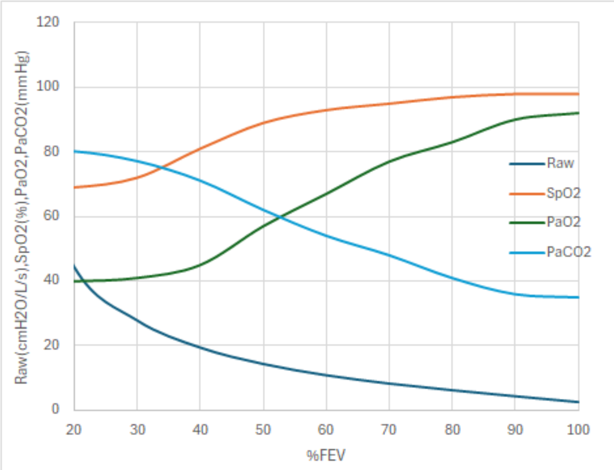
Airway resistance RAW is,

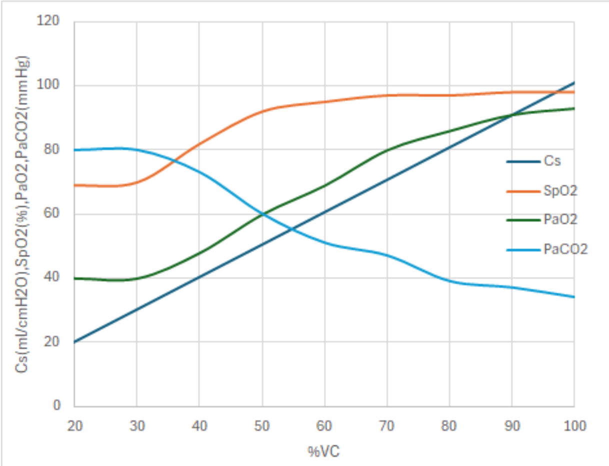
$$e^{-\frac{1}{C_S R_{AW}}} = 1 - \frac{FEV_1\%}{100} \quad \Rightarrow -\frac{1}{C_S R_{AW}} = \ln\left(1 - \frac{FEV_1\%}{100}\right)$$

$$\Rightarrow R_{AW} = -\frac{1000}{C_S \cdot \ln\left(1 - \frac{FEV_1\%}{100}\right)} \quad (cmH2O / L / s)$$

However, the maximum value of FEV1% is 98.5% to approximate the representative value in clinical practice.

Examples of changes in biometric information with respect to the severity of obstructive and restrictive ventilatory disorders are shown below.



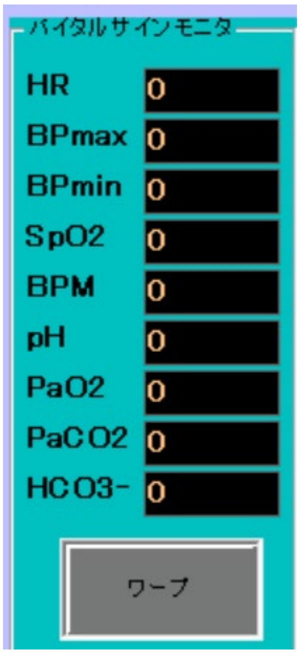


<u>Obstructive Ventilation Disorder</u> <u>Restrictive Ventilation Disorder</u>

(Patient Parameters)

Height: 167 cm, Weight: 60 kg Age: 20 years old

Respiratory rate: 12 bpm Intrathoracic pressure: 10 cmH2O

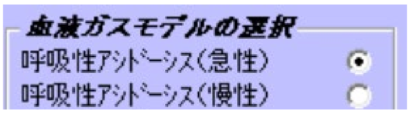


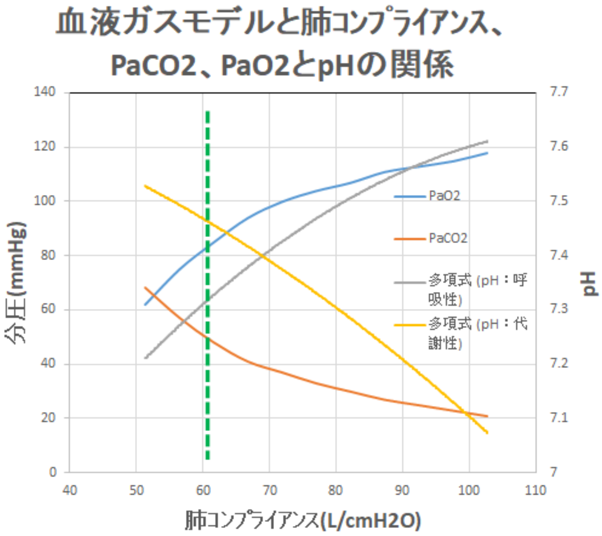
The results of the settings are reflected in the blood gas information after a 10-20 second delay. Waiting for this can be very time consuming, so we have added a time acceleration function to reduce that time cost.

By pressing the warp button on the left, the progression of time is accelerated by a factor of 3 to 5, depending on the performance of the PC.

Please note that when returning from warp, the graph display will not be able to keep up for a while and will stop, but will recover after a while.

(7) Acid-base balance (respiratory and metabolic acidosis/alkalosis) in virtual patients





You can simulate changes in HCO3$^-$ and pH due to respiratory and metabolic acidosis by selecting the Significance band formula model on the "Select Blood Gas Model" shown on the left.

As shown in the left figure, when lung compliance is reduced as a reproduction of restricted ventilatory failure, pH decreases in respiratory acidosis due to an increase in PaCO2, whereas in metabolic acidosis pH also increases due to an increase in HCO3$^-$.

One limitation of this mathematical model is that PaCO2 = 40 mmHg will always result in pH = 7.4.

We hope you will understand that this is an issue for future consideration.

Chapter 5 Operation of Trend Graph Display Panel

On this title screen before executing the session

CODE: Arbitrary string indicating training content

DATE: Today's date

Trial No: Trial No. (Press R to reset to 0)

If you set up a,

A trend file with biometric and investigative information about the training named CODE + DATE + Trial No.csv is automatically saved in the following folder every second.

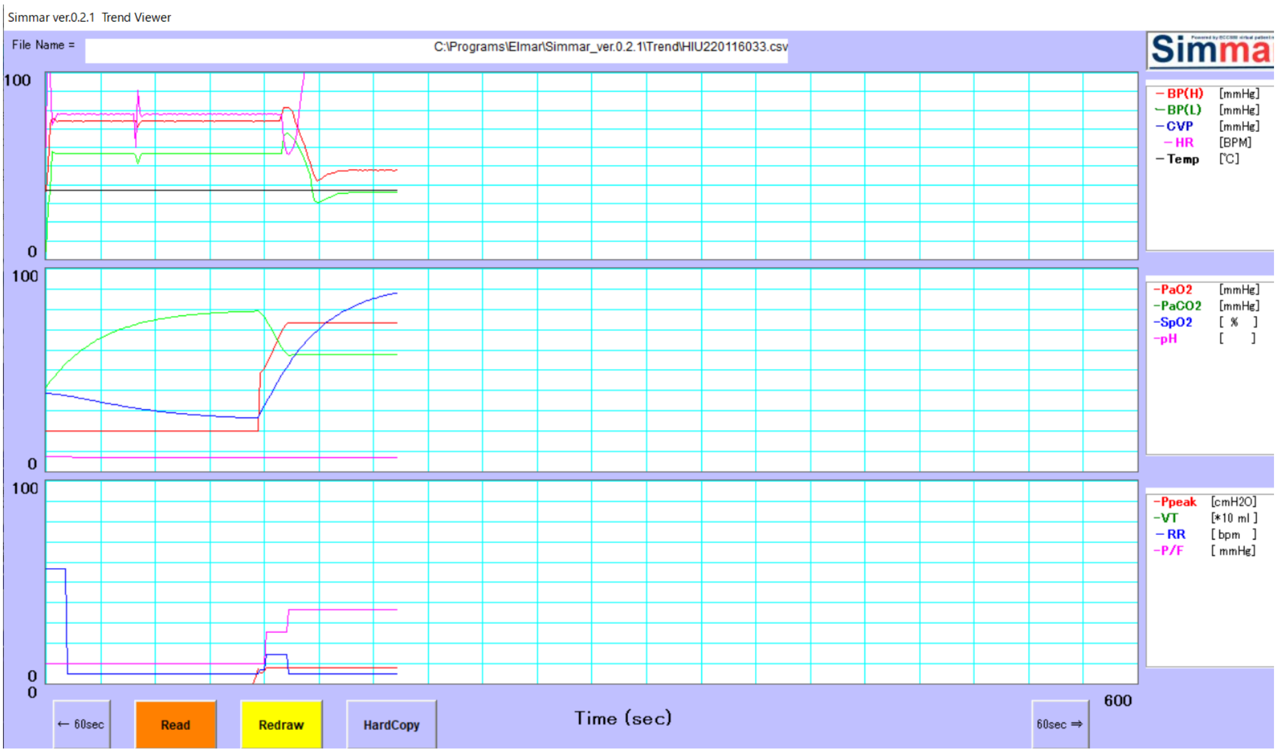
C:\Programfiles(x86)\Simmar)Trend folder

Specifically, in the example above, it is recorded under the file name HIU220117038.csv.

This file can be imported into Excel or other spreadsheet software, so if you know how to use Excel, you can perform quantitative analysis of training results.

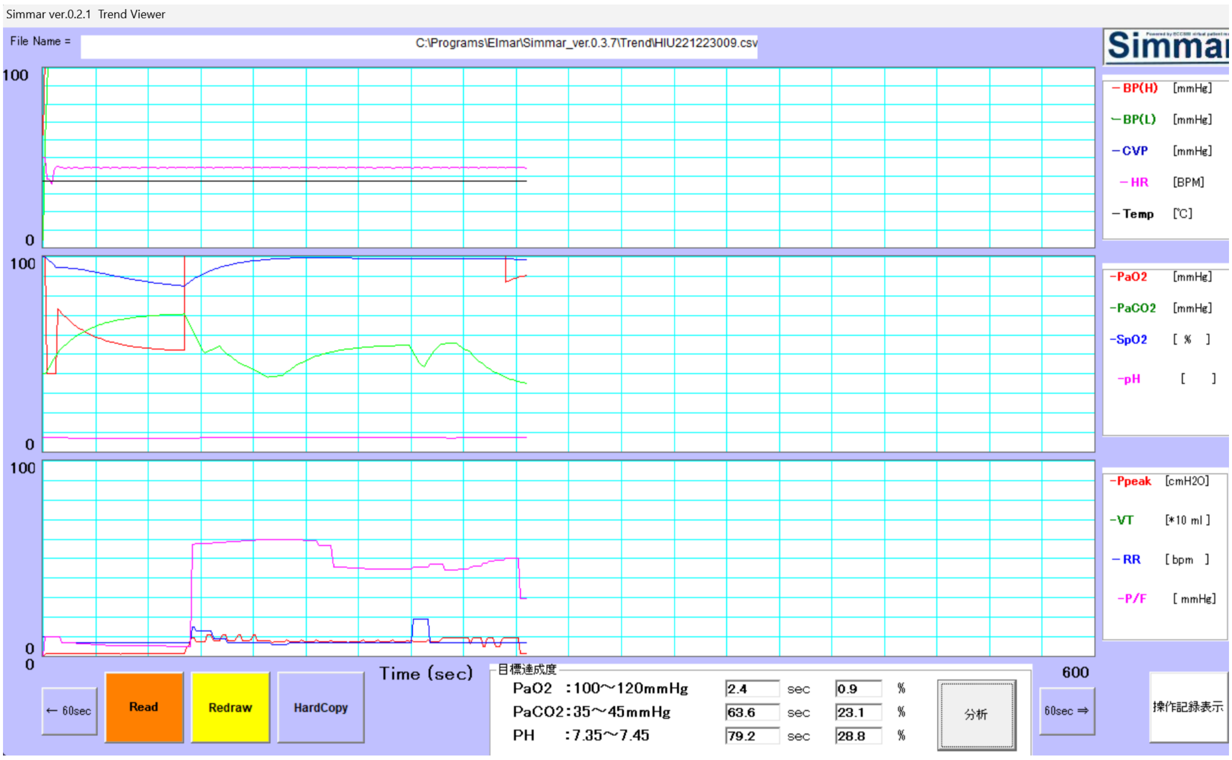
To quickly view (a portion of) the contents of the trend graph, click on (1) "Check Trend Graph".

By clicking the "READ" button and selecting the name of the trend file you wish to view, the graph will be displayed as shown below. To change the scale, rewrite the values on the vertical and horizontal axes as appropriate and click the "REDRAW" button.



Although only a simple display function has been realized, we plan to improve it to a specification where the display items can be freely edited at some point. This is an important function for reviewing training, so if you have any suggestions for improvement, please do not hesitate to let us know.

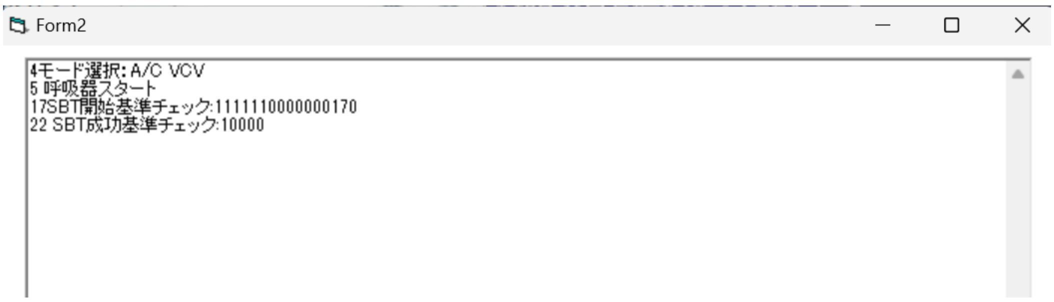
(1) Addition of objective evaluation function in trend graphs



Clicking on the "Analyze" button in the Target Attainment panel will calculate the time that PaO2, PaCO2, and PH were in the normal range and the percentage (%) of that time. The closer to 100%, the better for the organism.

(2) Display of operation records

Clicking the Display Operation Record button displays the operation record, including mode settings.



Enter the captions and the elapsed time for each as appropriate, and press "Calculate Time". The narration start time will be calculated.

When you have finished creating your scenario, be sure to click on the last line of the scenario and press the "Last Line" button. This is where the scenario will be saved. Rows that will be saved will be white, and those that will not be saved will be gray.

Click on the caption, and it will turn yellow. You can "Insert" and "Delete" for this line.

The ▲ ▼ buttons scroll through the rows. Up to 1000 lines can be edited.

Each time you change the elapsed time, press "Calculate Time" just to be sure.

The combo box is used to register a fixed sentence. When a registered sentence is displayed and inserted, the corresponding audio file is inserted in the yellow line.

Pressing the "Run Scenario" button will take you to the session screen for training.

As a new function from Ver. 0.3.4, the pathological state can be generated at a specified time by entering the pathological state number set in the pathological state selector of the patient setting panel in the Event field. The number 0 is normal (Control), 1 and 2 are reserved numbers for reproduction of myocardial protection, and 3 and after can be set freely. (Tdiv is the variation range to randomly change the start time, not implemented in Ver. 0.3.4)

[Attention.

Incorrect input operations may cause the system to freeze in rare cases. To avoid wasting work, please save your scenario frequently. If the result of a scenario change is not reflected at runtime, save and reload the scenario.

Chapter 7 Serial Communication with ESTE-SIM

Step.1 Connecting Simmar Tablet and VP-ECMO

Connect the USB-Type C hub to the USB-Type C terminal on the Simmar tablet and connect the Type A terminal on the hub to the Type B terminal on the controller using a USB cable (cable for printer or external hard disk).

Step.2 Start Simmar

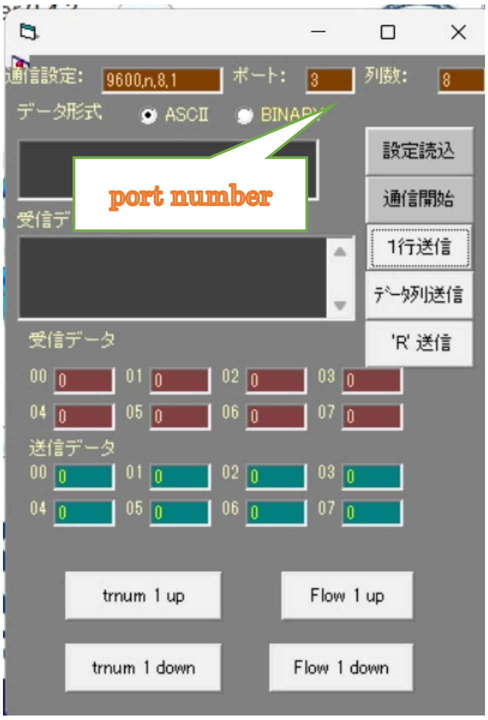
Double-click the "Simmar" icon on the desktop to start Simmar.

The version of Simmar at the time this manual was prepared was 1.0.2.

When the startup menu screen appears, click on "Case 3" in the "Case Selection" panel on the right.

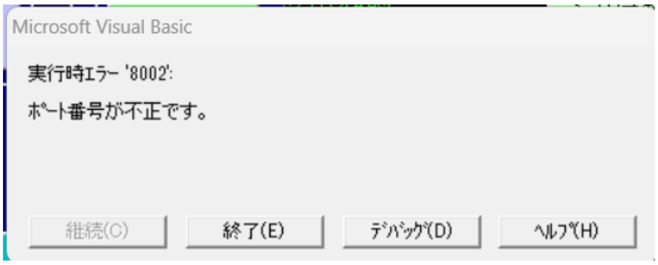
To link ESTE-SIM and Simmar, click the "Serial Communication Settings" button under "Various Settings".

Step.3 Setting up serial communication



When the serial communication setup panel opens, enter the port number to which the VP-ECMO controller is connected,

Click the "Read Settings"→ "Start Communication" button in turn. If the port number is incorrect, the program will exit with the following message



In this case, use the following method to find the correct port number and start Simmar again to reconfigure it (once reconfigured, Simmar will remember the number, so you will not need to do this again). (Once reconfigured, Simmar will remember the number and you will not need to do this again.)

How to check the port number to which VP-ECMO is connected

(Note) The way to do this depends on the version of Windows. Here we explain how to do it on Windows 11. For other versions, please search for "Windows", "COM port", "Arduino", etc. Please check it out.

① Go to *"Windows" > "Settings" > "Bluetooth and Devices."*

② Select *"Devices"* and you will see a list of connected devices as shown on the left. To the right of the "Arduino Uno" item, the port number is shown. In the example on the left,
Port number = 6.

Step. 4 Confirmation of serial communication operation

If the correct port number is entered, the display of the "Start Communication" button changes to "Stop Communication" and communication with VP-ECMO is established, as shown on the left.

The data received from the VP-ECMO controller is sequentially displayed in the "History of Received Data" box. The breakdown of received data is as follows

00: Respirator disconnect flag: 1/0 = connected/disconnected

In addition, the breakdown of data sent to the ESTE-SIM will be as follows

00: Respiration flag (inhalation/exhalation = 1/0)
01: SpO2 (%)
02: HR (bpm)
03: PaO2 (mmHg)
04: PaCO2(mmHg)
05:pH

Step. 5 Open the Respiratory Console

Simmar is designed to work with both ESTE-SIM (sputum suction VR simulator) and VP-ECMO.

The following is the procedure for setting up interlocking with VP-ECMO.

Reference] Approximation Model of Sigmoid Function of Lung Compliance for Simmar

The following sigmoid function approximates the relationship between lung capacity Vc(ml) lung air volume and internal pressure.

$$V(p) = \frac{Vc}{1+e^{-ap}} \quad \ldots(1)$$

(1) Differentiate the equation by p. From the fractional derivative formula shown on the right $\left(\frac{1}{f(x)}\right)' = -\frac{f'(x)}{f(x)}$

$$\frac{dV(p)}{dp} = \frac{d}{dp}\left(\frac{Vc}{1+e^{-ap}}\right) = -\frac{Vc}{\left(1+e^{-ap}\right)^2}\cdot\frac{d}{dp}\left(1+e^{-ap}\right) = -\frac{Vc}{\left(1+e^{-ap}\right)^2}\cdot\left(-ae^{-ap}\right)$$

$$= \frac{a \cdot Vc \cdot e^{-ap}}{\left(1+e^{-ap}\right)^2} \quad \ldots(2)$$

Since the slope of the PV curve at p=0 is the static lung compliance, let the static lung compliance be Cs,

$$\frac{dV(0)}{dp} = Cs \quad \ldots(3)$$

Therefore, the coefficient a is,

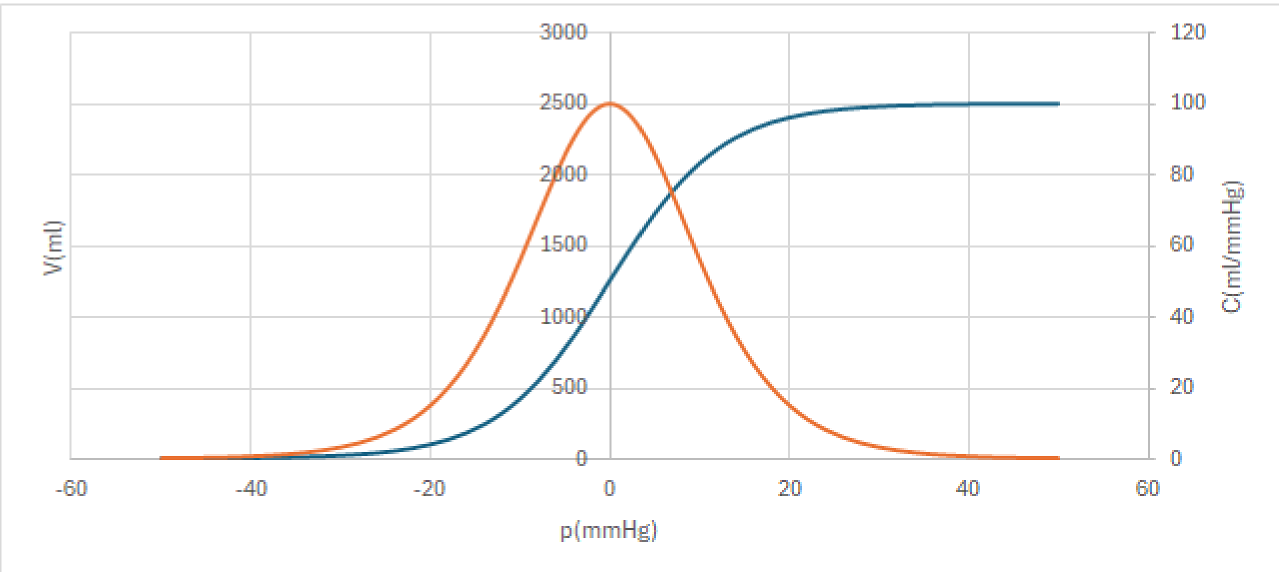
$$\frac{a \cdot Vc}{4} = Cs \quad \rightarrow \quad a = \frac{4Cs}{Vc} \quad \ldots(4)$$

From the above discussion, the compliance change at any given pressure is

$$C(p) = \frac{Vc \cdot a \cdot e^{-ap}}{\left(1+e^{-ap}\right)^2} \quad \ldots(5)$$

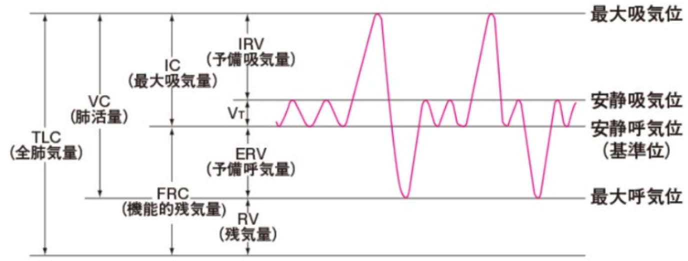
The first is the "M" in the "M" column.

An example of the calculation of intrapulmonary pressure and lung air volume and compliance at Vc=2500 ml and Cs=100 ml/cmH2O is shown below.



VC curve shift model to reproduce the effect of PEEP

It is known that applying PEEP causes collapsed alveoli to expand and increases lung progressivity (compliance). By shifting the sigmoid function in the positive pressure direction, the increase in progressivity due to sustained positive pressure and the decrease in lung compliance due to excessive positive pressure can be simulated.



From the spirogram, it can be seen that the lungs breathe in the VC range, centered at ERV＋ 1/2V(T). Also, from IRV＞ ERV, the most evolved lung air volume in the sigmoid function model is located on the positive pressure side relative to atmospheric pressure.

In other words, it is a numerical model in which lung compliance is increased by applying appropriate PEEP (positive air pressure).

肺気量分画の名称：略号：正常値(成人２０～３０歳)				
(分画の名称)	(英語名称)	(略号)	(ml)	(%)
予備呼気量	Inspiratory Reserve Volume	IRV	3100	67%
１回換気量	Tidal Volume	TV	500	11%
予備呼気量	Expiratory Reserve Volume	ERV	1000	22%
残気量	Residual Volume	RV	1300	28%
最大吸気量	Inspiratory Capacity	IC	3600	78%
機能的残気量	Functional Residual Capacity	FRC	2399	52%
肺活量	Vital Capacity	VC	4600	100%
全肺気量	Total Lung Capacity	TLC	5900	128%

From representative values of lung air volume fractions,

(ERV+1/2VT)/VC=27.2% Therefore,

VC/(ERV+1/2VT)=3.68

(1) From the formula
$$e^{-\alpha P} = \frac{V_C}{V(p)} - 1 \quad \rightarrow \quad p = -\frac{1}{\alpha}\ln\left(\frac{V_C}{V(p)} - 1\right) \quad \text{...(6)}$$

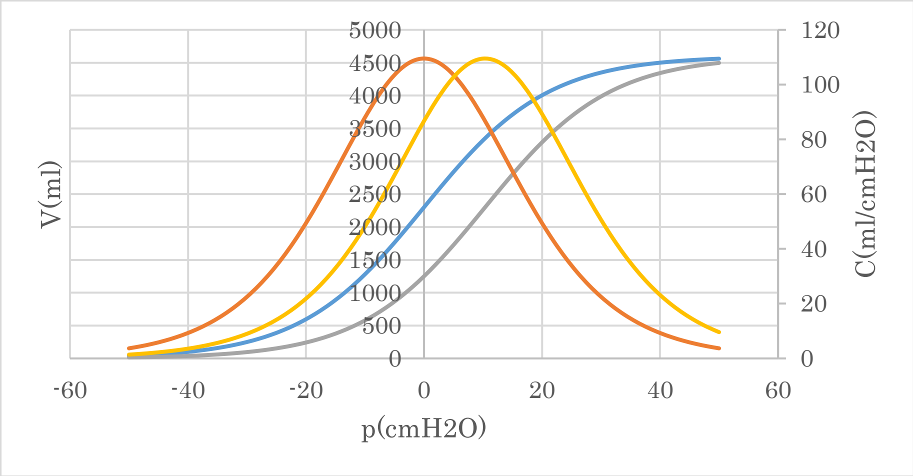
Therefore, the positive pressure Δp at which lung compliance is maximal is,

$$\frac{V_C}{V(p)} = \frac{V_C}{ERV + {}^{1}\!/_{2} \cdot V_T} = 3.68 \quad \rightarrow \Delta p = -\frac{0.986}{\alpha} \quad \text{...(7)}$$

The lung compliance considering pressure shift is
$$C(p) = \frac{V_C \cdot \alpha \cdot e^{-\alpha(p+\Delta p)}}{\left(1 + e^{-\alpha(p+\Delta p)}\right)} \quad \text{...(8).}$$

An example of the calculation of intrapulmonary pressure and lung air volume and compliance at Vc=4600 ml and Cs=109.5 ml/cmH2O is shown below.

α=0.0952, Δp=-10.35cmH2O



V(ml)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
120
100
80
60
40
20
0
C(ml/cmH2O)
-60
-40
-20
0
20
40
60
p(cmH2O)