My Maiden Wechat Mini Program:
Auto Set Alarm Limits Calculation

A, Introduction

Noise pollution in hospital is negatively affecting the nurses. It is estimated that one patient monitor will sound an alarm of various types every several minutes. And 80% to 90% of these alarms do not reflect that the patient is deteriorating. For example, technical alarms saying "sensor off patient", or physiological alarm due to sudden patient action. So nurses are flooded with enormous number of alarms and their attention may be distracted by unimportant ones.

However, not all alarms can be deducted, owning to security purposes and standard requirements. Here, we are focusing on one specific compliant: *the default alarm limits are above or below normal status of some patients.* For example, when a patient is in normal status, his / her body temperature is around 37.3 degree. Redundant alarms will be registered constantly, to alert the operators that this patient has a fever.

Thus, "auto set alarm limits" functionality in modern patient monitors is provided to customers as the solution to their complaint. This functionality allows the operator to rapidly *adjust alarm high and low limits according to **currently** measured vital signs*. As the adjusted range is increasingly adapted to the measured value, the alarm will not be registered as frequently as before, and thus reducing the number of unnecessary alarms.

The algorithm of "auto set alarm limits" is so sophisticated that testing this functionality requires the tester to switching among three files: range of measurement, factory defaults of alarm limit range, and auto set alarm algorithms. Therefore, the significance of designing this program is to facilitate the work of software quality engineers by allowing them to calculate expected adjusted alarm limits within a few seconds.

B, Customer requirement specifications

Enter a measured vital sign and its relevant parameters.

Post the adjusted alarm limits.

The results should be equal to the alarm limits after clicking "auto set alarm limits" on patient monitors.

C, System requirement specifications

1, Index page

On the title bar, there is the abbreviation form of this mini program.

In the middle, there is the complete name and image of "auto set alarm limits" functionality. Clicking either the name or the image will navigate to the page in which this functionality is implemented.

On the bottom, there is a the name of the mini program in Italian, and program version number. The version number is written in this format: <Alphabetic letter>. <Main version number>. <Sub version number>.

2, Measurement Info page

Operator can be navigated to this page via clicking the image or the name of "auto set alarm limits" functionality in index page.

On the title bar, "auto set alarm limits" or a relevant phrase is written.

In the middle of this page, users can select parameters of the current vital signs measurements. The indices and parameters are listed as below:

I1	Panes	I2	Parameters	I3	Units	Valid range
0	CO2	0	etCO2	0	mmHg	[0, 150]
				1	kPa	[0.0, 20.0]
		1	imCO2	0	mmHg	[0, 150]
				1	kPa	[0.0, 20.0]

		2	IPI	0	N/A	[1, 10]
1	NBP	0	Systolic	0	mmHg	[30, 270]
				1	kPa	[4.0, 36.0]
		1	Map	0	mmHg	[20, 250]
				1	kPa	[2.7, 33.3]
		2	Diastolic	0	mmHg	[10, 240]
				1	kPa	[1.3, 32.0]
2	Pulse	0	From P.SpO2	0	bmp	[30, 300]
		1	From M.SpO2	0	bmp	
		2	From NBP	0	bmp	
3	Resp	0	From awRR	0	rmp	[0, 150]
		1	From RRa	0	rmp	
4	SpO2	0	P.SpO2	0	%	[0, 100]
		1	M.SpO2	0	%	
		2	SpHb	0	g/dL	[0.0, 25.0]
				1	mmol/L	[0.0, 15.5]
5	Temp	0	Predictive	0	C	[30.0, 41.0]
				1	F	[86.0, 105.8]
		1	Tympanic	0	C	[30.0, 41.0]
				1	F	[86.0, 105.8]
		2	Temporal	0	C	[30.0, 41.0]

				1	F	[86.0, 105.8]
	3	Cradle		0	C	[30.0, 41.0]
				1	F	[86.0, 105.8]

Table 1

* "I" stands for "index".

Panes, Parameters and Units are of type pop-up list. And there is one more pop-up list: patient type. Patient type has three choices: Adult, Pediatric and Neonatal.

Additionally, "Valid range", the last column of Table 1, will be shown whenever the three pop-up lists change their value. The value of "Valid range" is independent of patient type selection.

Beneath "Valid range", there is a insertion box, in order to let the operator to enter the value of current measured vital signs. A click on the input box will pop out a digital keyboard.

After that, there is the calculation button with a name, such as "Auto Set Alarm Limits". A click on this button will start to compute the adjusted alarm limits. If inserted value is beyond valid range, a message will be shown under this button. Otherwise, the adjusted alarm limits will be computed and mini program will navigate the operators to the Computation Result page.

Some of the parameters are not available of certain kind of patient.

Unavailable parameter	Patient type
SpHb	Neonatal
IPI	Pediatric and neonatal
Resp, from RRa	Neonatal
imCO2 high limit	All patients

IPI high limit	All patients

Table 2

In case of the above combinations, a message indicating unavailable combination will be shown. And insertion box and calculation button will be hidden.

3, Computation Result page

On the title bar, the same phrase is written as its previous page.

Furthermore, two fields show the result of auto set alarm limits. The results could be either numbers or some phrases indicating the original alarm limits will be kept.

Last but not least, in case of a NBP measurement, a sentence asserting whenever one alarm limits remain unchanged, all will be not changed will be displayed.

4, Auto set alarm limits algorithm

To check the detailed algorithm, please refer to product Instruction of Usage, chapter: (1), factory default and range of alarm limits. (2), auto set alarm limits.

Here is the designed program pattern:

> (1), check indices, in order to figure out which parameter and what kind of patient are we dealing with.
>
> (2), compute according to auto set alarm limits formula to get the alarm limits that intended to set with.
>
> (3), check whether the intended values are within the range of alarm limits.
>
> (4), if they are within the range, set accordingly.
>
> (5), otherwise, alarm limits remain unchanged.

D, Test plan

According to the designed program pattern, the numbers can be classified into five independent intervals.
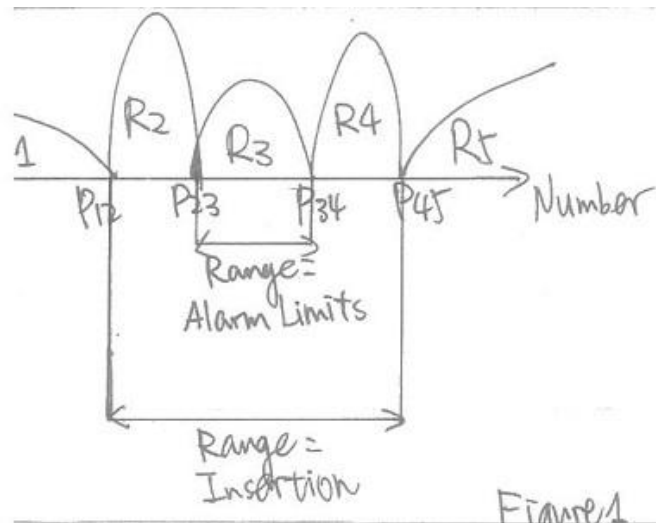

Figure 1

The five ranges and their cross points are demonstrated in Figure 1. Their significance is listed as below:

Range NO	Illustration	Result type
1	Smaller than insertion range.	invalid insertion
2	Within insertion range. But after auto set alarm limits computation, the intended results is smaller than range of alarm limits.	no change
3	Within insertion range. And after computation, alarm limits can be adjusted.	some number
4	Within insertion range. But after auto set alarm limits computation, the intended results is larger than range of alarm limits.	no change
5	Larger than insertion range.	invalid insertion

Table 3

Thus, two aspects must be taken into consideration in order to yield the conclusion that this mini program is reliable. (1), cross points of these five ranges. (2), representative numbers with in these five ranges.

E, Test cases

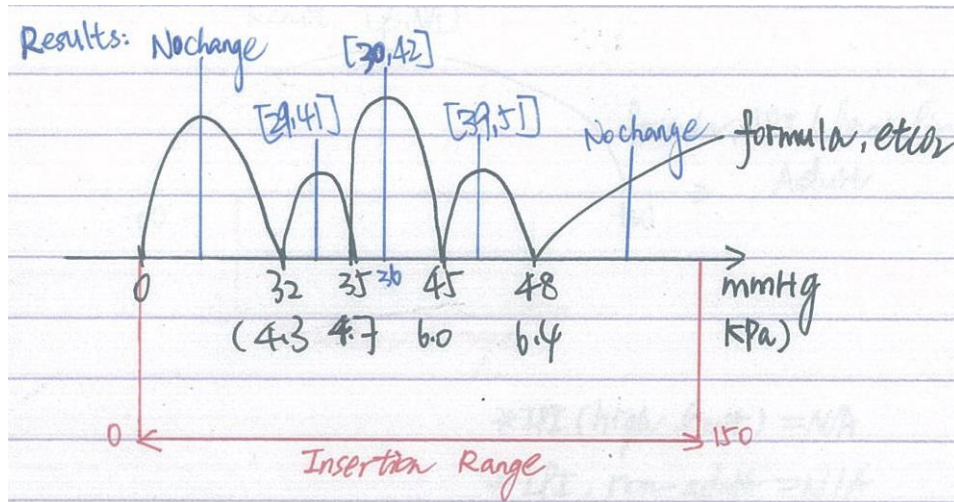ATTENTION: The graphs in this section are not draw to scale.

1, etCO2

Figure 2

1.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	0	N/A	N/A	150
kPa	0.0	N/A	N/A	20.0

Table 4

1.2, Endpoints that separate formula ranges

Unit	Formula range 1	Formula range 2	Formula range 3	Formula range 4
mmHg	32	35	45	48
kPa	4.3	4.7	6.0	6.4

Table 5

1.3, Recommended test cases

Although alarm limits range is not applicable in this case, the formula is divided into several computational areas. Thus, it is more reliable to incorporate all (at least some) of the endpoints and intervals of various formula ranges.

Case NO	Content (CO2, etCO2)	Acceptance Criteria
1	mmHg, <all patient types>, 151 kPa, <all patient types>, 21.0	Out of insertion range
2	mmHg, <all patient types>, 0 kPa, <all patient types>, 0.0 mmHg, <all patient types>, 150 kPa, <all patient types>, 20.0	High: No change Low: No change
3	mmHg, <all patient types>, 32 kPa, <all patient types>, 4.3 mmHg, <all patient types>, 49 kPa, <all patient types>, 6.5	High: No change Low: No change
4	mmHg, <all patient types>, 35	High: 41 Low: 29
5	kPa, <all patient types>, 4.7	High: 5.5 Low: 3.9
6	mmHg, <all patient types>, 45	High: 51 Low: 39
7	kPa, <all patient types>, 6.0	High: 6.8 Low: 5.2

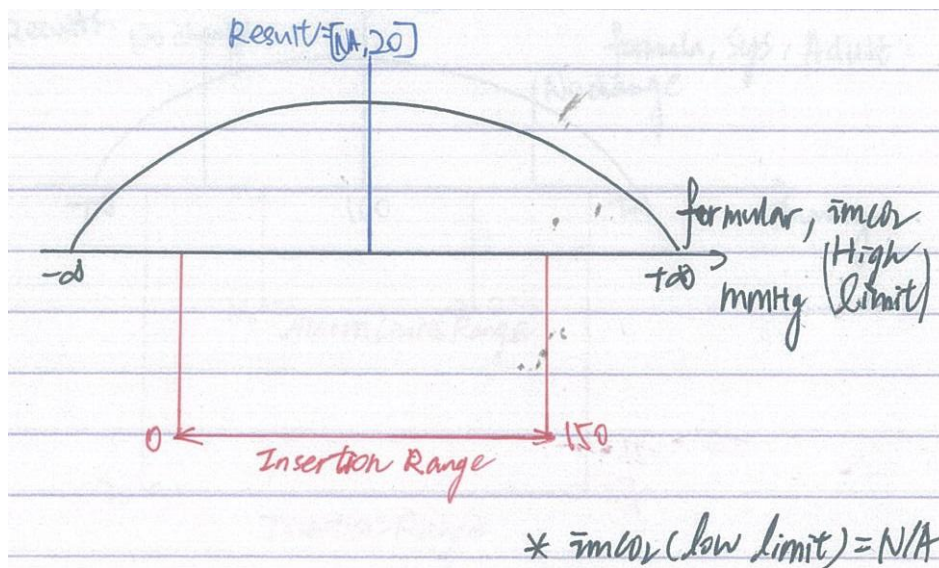| 8	mmHg, <all patient types>, 48	High: 51 Low: 39
9	kPa, <all patient types>, 6.4	High: 6.8 Low: 5.2

Table 6

2, imCO2

Figure 3

2.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	0	N/A	N/A	150
kPa	0.0	N/A	N/A	20.0

Table 7

2.2, Recommended test cases

| Case NO	Content (CO2, imCO2)	Acceptance Criteria
1	mmHg, <all patient types>, 151 kPa, <all patient types>, 21.0	Out of insertion range
2	mmHg, <all patient types>, 0 mmHg, <all patient types>, 150 mmHg, <all patient types>, 100	High: 20 Low: N/A
3	kPa, <all patient types>, 0.0 kPa, <all patient types>, 20.0 kPa, <all patient types>, 10.0	High: 2.7 Low: N/A

Table 8

3, IPI
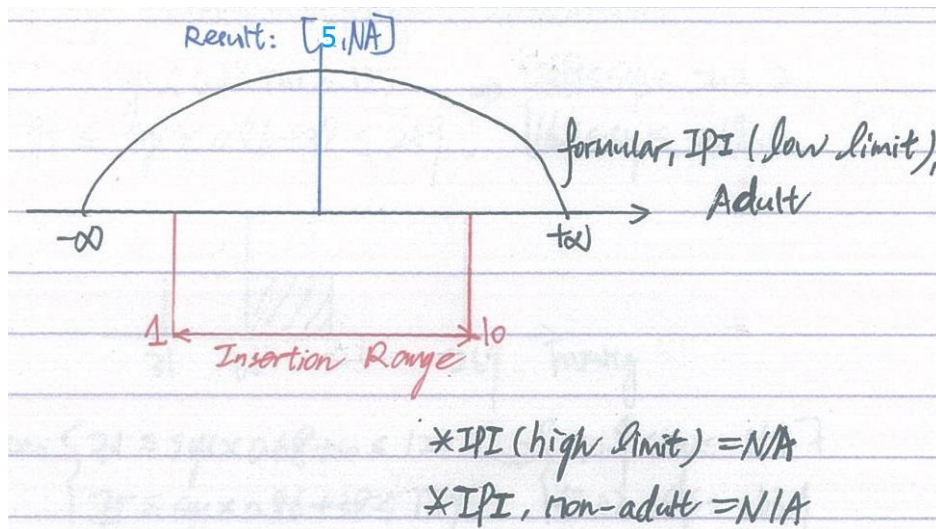
Figure 4

3.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)

N/A	0	N/A	N/A	10

Table 9

3.2, Recommended test cases

Case NO	Content (CO2, IPI)	Acceptance Criteria
1	Adult, 0 / Adult, 11	Out of insertion range
2	Adult, 1 Adult, 10 Adult, 3	High: N/A Low: 5
3	!Adult	Unsupported combination

Table 10

4, NBP, SYS, adult
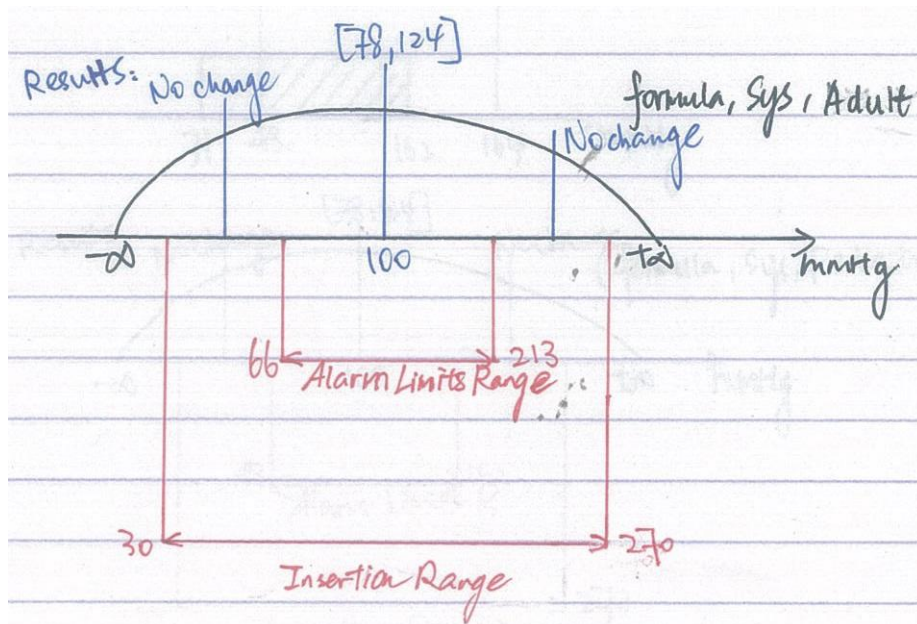
Figure 5

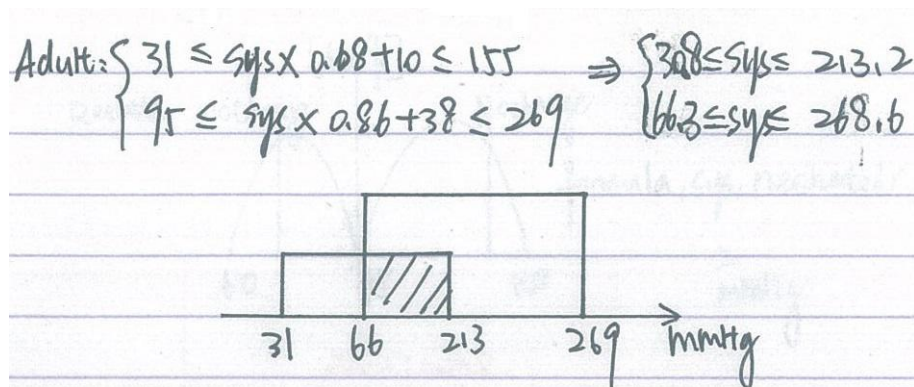## 4.1, Endpoints that separate insertion and alarm limits ranges

Figure 6

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	30	66	213	270
kPa	4.0	8.8	28.5	36.0

Table 11

4.2, Recommended test cases

Case NO	Content (NBP, SYS, adult)	Acceptance Criteria
1	mmHg, 29 / mmHg, 271 kPa, 3.9 / kPa, 36.1	Out of insertion range
2	mmHg, 30 / mmHg, 270 kPa, 4.0 / kPa, 36.0	High: No change Low: No change
3	mmHg, 66 / mmHg, 214 kPa, 8.8 / kPa, 28.6	High: No change Low: No change
4	mmHg, 67	High: 96 Low: 56

5	mmHg, 213	High: 221
		Low: 155
6	kPa, 8.9	High: 12.8
		Low: 7.4
7	kPa, 28.5	High: 29.6
		Low: 20.7

Table 12

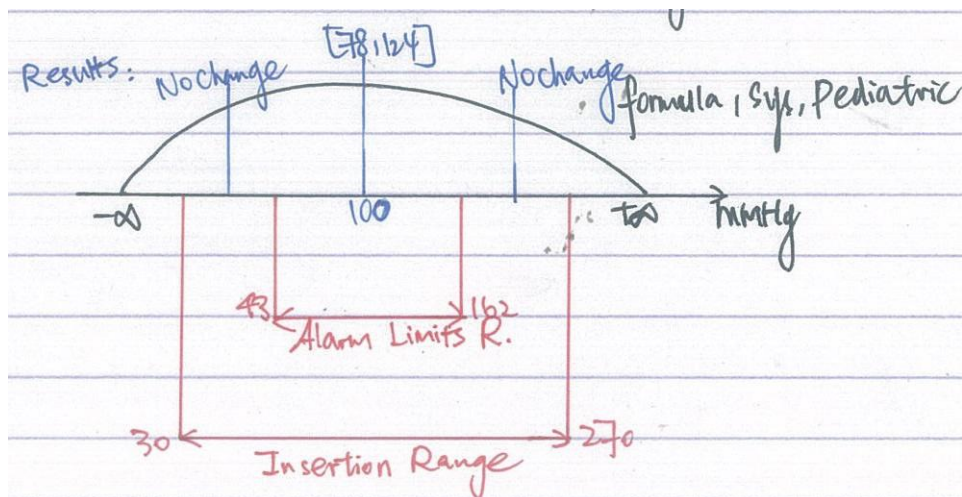## 5, NBP, SYS, pediatric

Figure 7

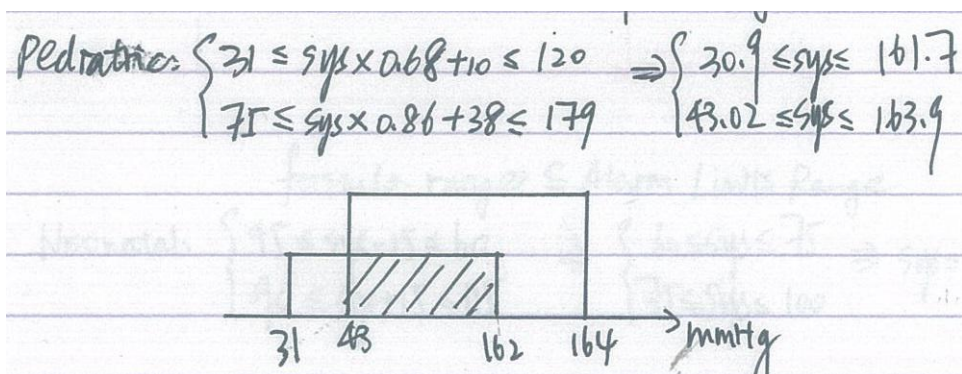## 5.1, Endpoints that separate insertion and alarm limits ranges

Figure 8

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	30	43	162	270
kPa	4.0	5.7	21.6	36.0

Table 13

5.2, Recommended test cases

Case NO	Content (NBP, SYS, pediatric)	Acceptance Criteria
1	mmHg, 29 / mmHg, 271 kPa, 3.9 / kPa, 36.1	Out of insertion range
2	mmHg, 30 / mmHg, 270 kPa, 4.0 / kPa, 36.0	High: No change Low: No change
3	mmHg, 43 / mmHg, 162 kPa, 5.6 / kPa, 21.7	High: No change Low: No change
4	mmHg, 44	High: 76 Low: 40
5	mmHg, 161	High: 176 Low: 119
6	kPa, 5.7	High: 10.0 Low: 5.2
7	kPa, 21.6	High: 23.7 Low: 16.0

Table 14
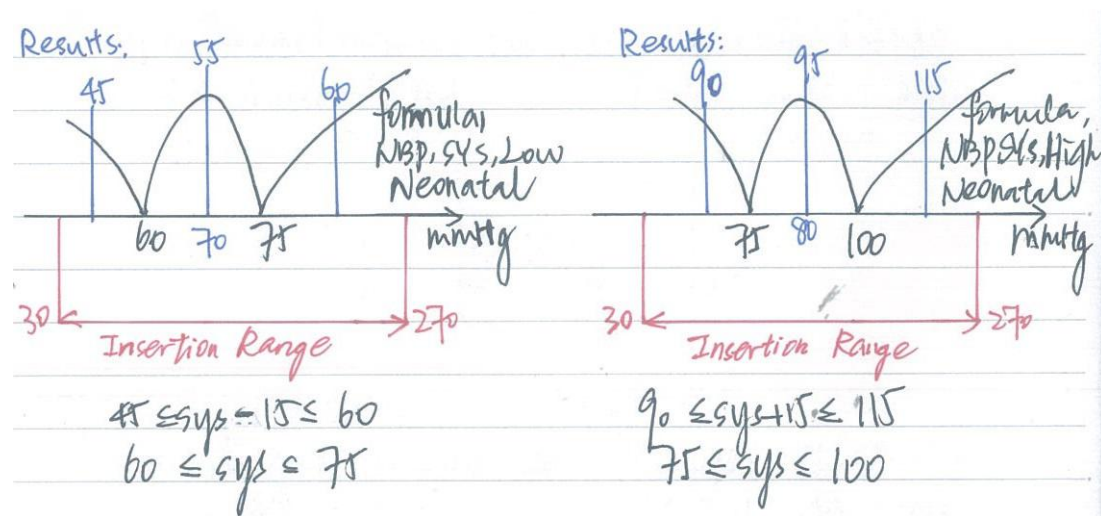
6, NBP, SYS, neonatal

Figure 9

6.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	30	N/A	N/A	270
kPa	4.0	N/A	N/A	36.0

Table 15

6.2, Endpoints that separate formula ranges

Unit	Low / high limits	Formula range 1	Formula range 2
mmHg	Low	60	75
kPa	Low	8.0	10.0
mmHg	High	75	100
kPa	High	10.0	53.3

Table 16

6.3, Recommended test cases

Case NO	Content (NBP, SYS, neonatal)	Acceptance Criteria
1	mmHg, 29 / mmHg, 271 kPa, 3.9 / kPa, 36.1	Out of insertion range
2	mmHg, 30 / mmHg, 60	High: 90 Low: 45
3	kPa, 4.0 / kPa, 8	High: 12 Low: 6
4	mmHg, 270 / mmHg, 100	High: 115 Low: 60
5	kPa, 36.0 / kPa, 13.3	High: 15.3 Low: 8
6	mmHg, 74	High: 90 Low: 59
7	kPa, 9.9	High: 12.0 Low: 7.9
8	mmHg, 75	High: 90 Low: 60
9	kPa, 10	High: 12.0 Low: 8.0
10	mmHg, 76	High: 91 Low: 60

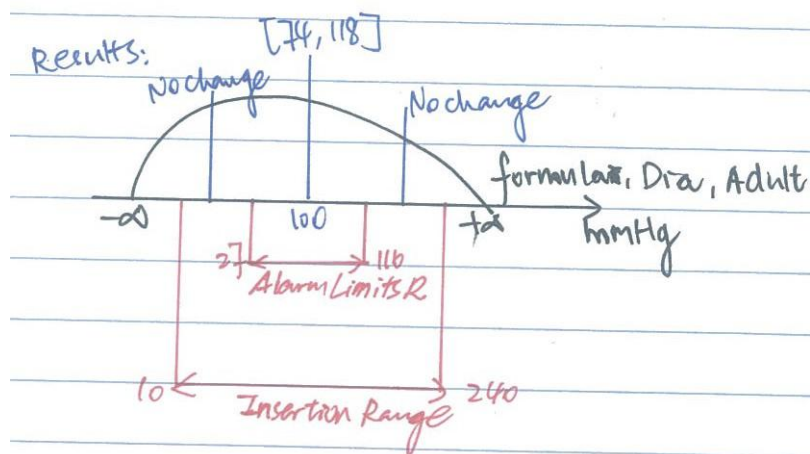| 11 | kPa, 10.1 | High: 12.1
 Low: 8.0 |
| 12 | mmHg, 99 | High: 114
 Low: 60 |
| 13 | kPa, 13.2 | High: 15.2
 Low: 8.0 |

Table 17

7, NBP, DIA, adult

Figure 10

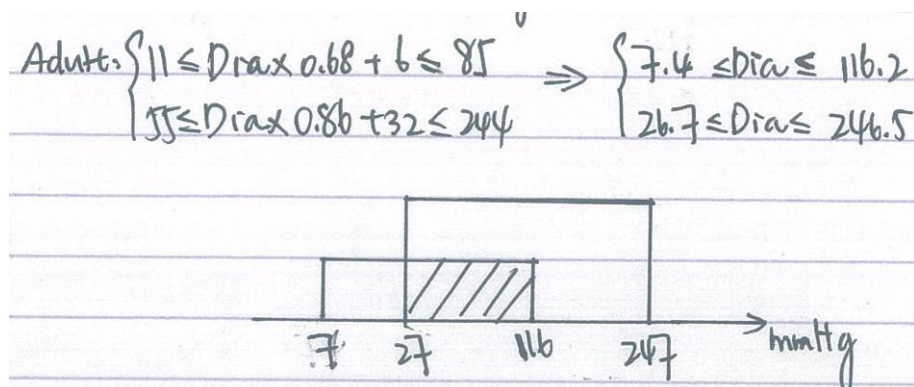## 7.1, Endpoints that separate insertion and alarm limits ranges

Figure 11

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	10	27	116	240
kPa	1.3	3.5	15.5	32.0

Table 18

7.2, Recommended test cases

Case NO	Content (NBP, DIA, adult)	Acceptance Criteria
1	mmHg, 9 / mmHg, 241 kPa, 1.2 / kPa, 32.1	Out of insertion range
2	mmHg, 10 / mmHg, 240 kPa, 1.3 / kPa, 32.0	High: No change Low: No change
3	mmHg, 26 / mmHg, 117 kPa, 3.4 / kPa, 15.5	High: No change Low: No change
4	mmHg, 27	High: 55 Low: 24
5	mmHg, 116	High: 132 Low: 85
6	kPa, 3.5	High: 7.3 Low: 3.2
7	kPa, 15.4	High: 17.5 Low: 11.3

Table 19

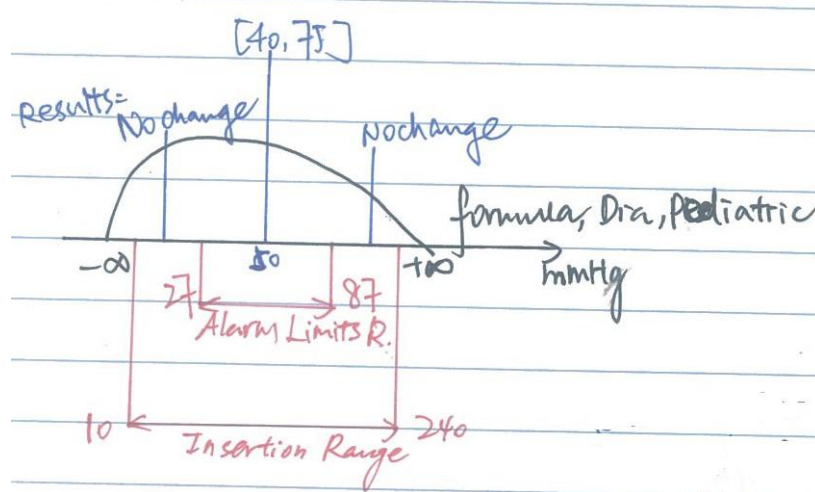## 8, NBP, DIA, pediatric

Figure 12

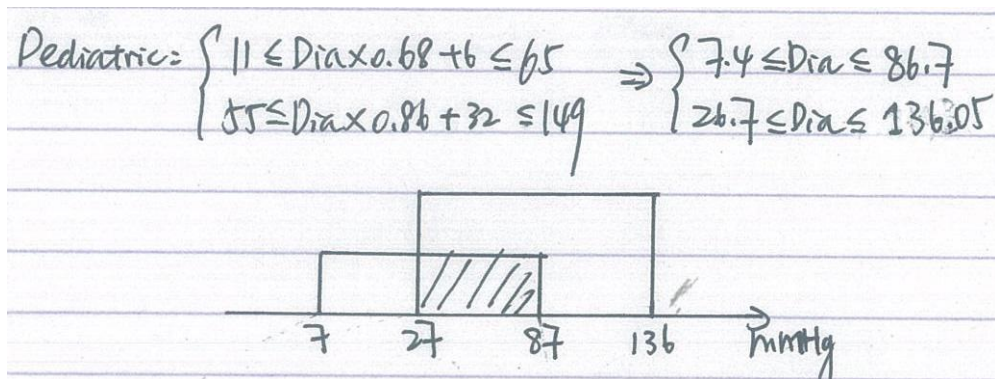## 8.1, Endpoints that separate insertion and alarm limits ranges

Figure 13

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	10	27	87	240
kPa	1.3	3.5	11.6	32.0

Table 20

8.2, Recommended test cases

Case NO	Content (NBP, DIA, pediatric)	Acceptance Criteria
1	mmHg, 9 / mmHg, 241 kPa, 1.2 / kPa, 32.1	Out of insertion range
2	mmHg, 10 / mmHg, 240 kPa, 1.3 / kPa, 32.0	High: No change Low: No change
3	mmHg, 26 / mmHg, 87 kPa, 3.4 / kPa, 11.7	High: No change Low: No change
4	mmHg, 27	High: 55 Low: 24
5	mmHg, 86	High: 106 Low: 64
6	kPa, 3.5	High: 7.3 Low:3.2
7	kPa, 11.6	High: 14.3 Low: 8.7

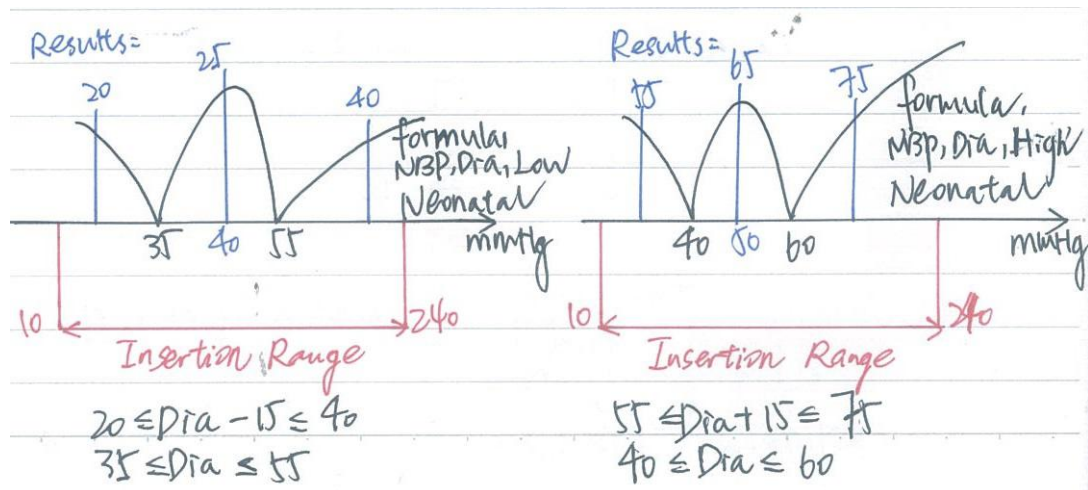Table 21

9, NBP, DIA, neonatal

Figure 14

9.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	10	N/A	N/A	240
kPa	1.3	N/A	N/A	32.0

Table 22

9.2, Endpoints that separate formula ranges

Unit	Low / high limits	Formula range 1	Formula range 2
mmHg	Low	35	55
kPa	Low	4.7	7.3
mmHg	High	40	60
kPa	High	5.3	8.0

Table 23

9.3, Recommended test cases

Case NO	Content (NBP, DIA, neonatal)	Acceptance Criteria
1	mmHg, 9 / mmHg, 241 kPa, 1.2 / kPa, 32.1	Out of insertion range
2	mmHg, 10 / mmHg, 35	High: 55 Low: 20
3	kPa, 1.3 / kPa, 4.7	High: 7.3 Low: 2.7
4	mmHg, 240 / mmHg, 60	High: 75 Low: 40
5	kPa, 32.0 / kPa, 8.0	High: 10.0 Low: 5.3
6	mmHg, 40	High: 55 Low: 25
7	kPa, 5.3	High: 7.3 Low: 3.3
8	mmHg, 55	High: 70 Low: 40
9	kPa, 7.3	High: 9.3 Low: 5.3
10	mmHg, 60	High: 75 Low: 40
11	kPa, 8.0	High: 10.0

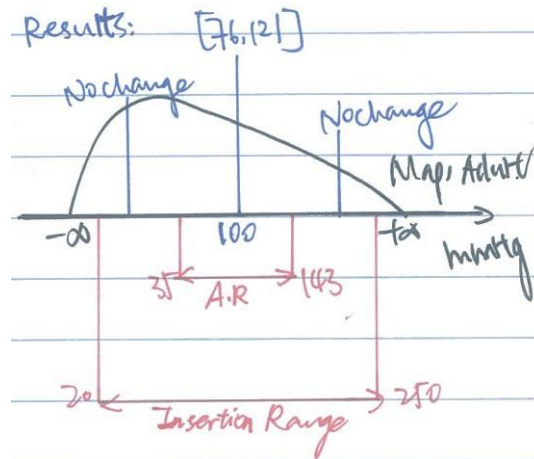|		Low: 5.3

Table 24

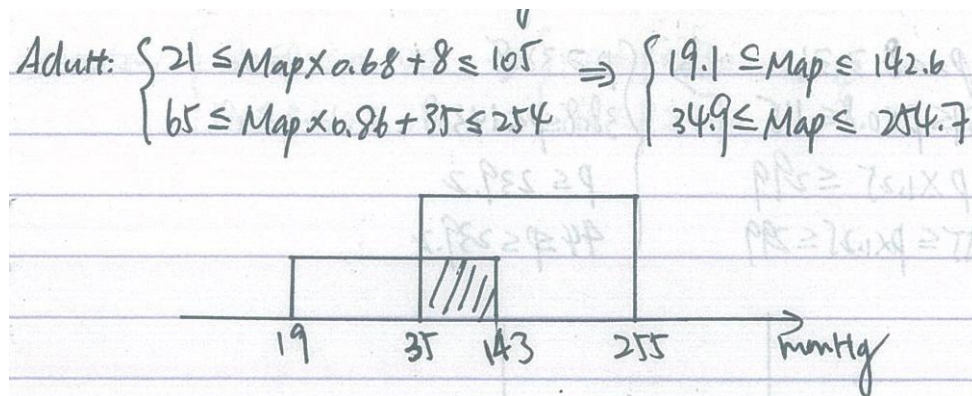## 10, NBP, MAP, adult

Figure 15

10.1, Endpoints that separate insertion and alarm limits ranges

Figure 16

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	20	35	143	250

kPa	2.7	4.7	19.0	33.3

Table 25

10.2, Recommended test cases

Case NO	Content (NBP, MAP, adult)	Acceptance Criteria
1	mmHg, 19 / mmHg, 251 kPa, 2.6 / kPa, 33.4	Out of insertion range
2	mmHg, 20 / mmHg, 250 kPa, 2.7 / kPa, 33.3	High: No change Low: No change
3	mmHg, 34 / mmHg, 143 kPa, 4.6 / kPa, 19.0	High: No change Low: No change
4	mmHg, 35	High: 65 Low: 32
5	mmHg, 142	High: 157 Low: 105
6	kPa, 4.7	High: 8.7 Low: 4.3
7	kPa, 18.9	High: 21.0 Low: 14.0

Table 26
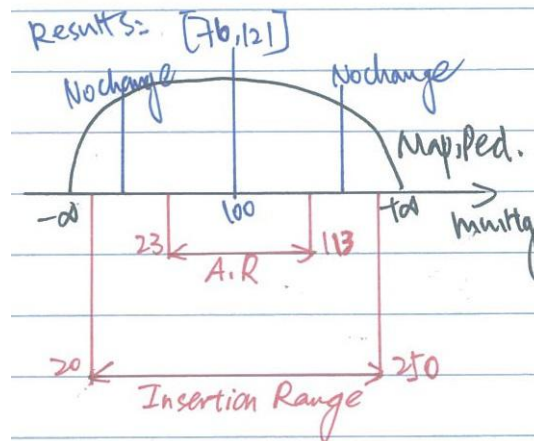
11, NBP, MAP, pediatric

Figure 17

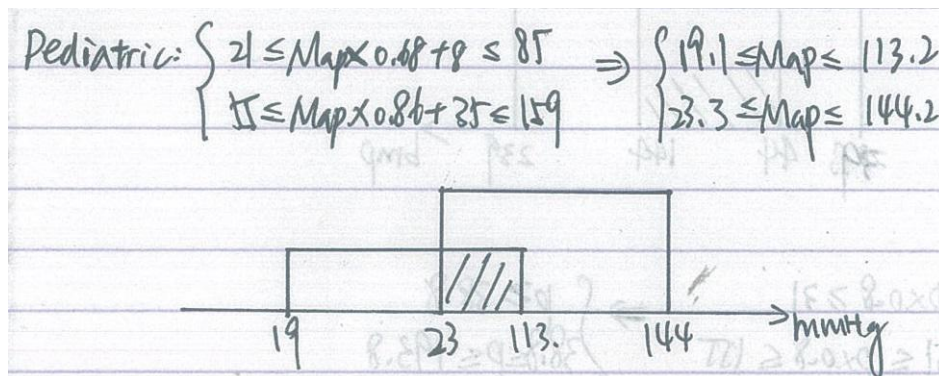## 11.1, Endpoints that separate insertion and alarm limits ranges

Figure 18

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	20	23	113	250
kPa	2.7	3.1	15.1	33.3

Table 27

11.2, Recommended test cases

Case NO	Content (NBP, MAP, pediatric)	Acceptance Criteria
1	mmHg, 19 / mmHg, 251 kPa, 2.6 / kPa, 33.4	Out of insertion range
2	mmHg, 20 / mmHg, 250 kPa, 2.7 / kPa, 33.3	High: No change Low: No change
3	mmHg, 23 / mmHg, 114 kPa, 3.1 / kPa, 15.1	High: No change Low: No change
4	mmHg, 24	High: 56 Low: 24
5	mmHg, 113	High: 132 Low: 85
6	kPa, 3.2	High: 7.5 Low: 3.3
7	kPa, 15.0	High: 17.6 Low: 11.3

Table 28
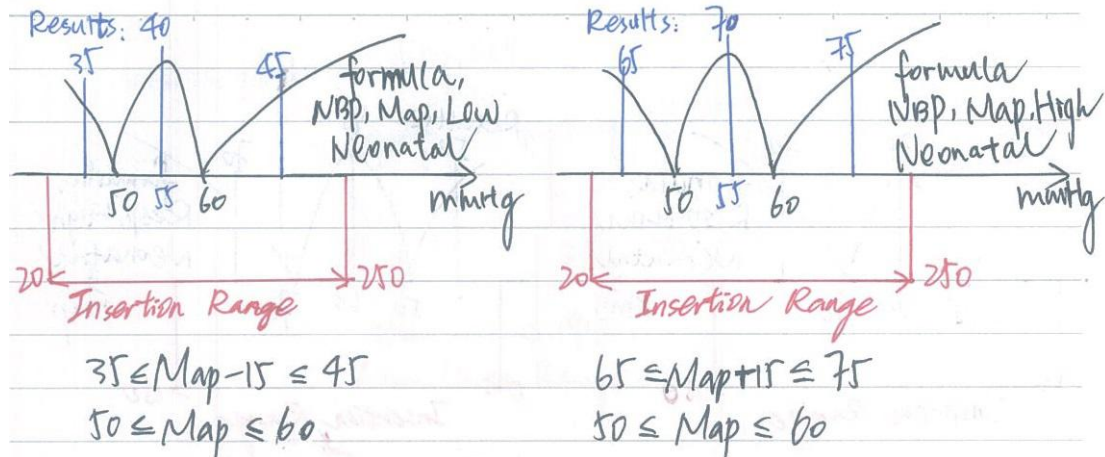
12, NBP, MAP, neonatal

Figure 19

12.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
mmHg	20	N/A	N/A	250
kPa	2.7	N/A	N/A	33.3

Table 29

12.2, Endpoints that separate formula ranges

Unit	Low / high limits	Formula range 1	Formula range 2
mmHg	Low	50	60
kPa	Low	6.7	8.0
mmHg	High	50	60
kPa	High	6.7	8.0

Table 30

12.3, Recommended test cases

Case NO	Content (NBP, MAP, neonatal)	Acceptance Criteria
1	mmHg, 19 / mmHg, 251 kPa, 2.6 / kPa, 33.4	Out of insertion range
2	mmHg, 20 / mmHg, 50	High: 65 Low: 35
3	kPa, 2.7 / kPa, 6.7	High: 8.7 Low: 4.7
4	mmHg, 250 / mmHg, 60	High: 75 Low: 45
5	kPa, 33.3 / kPa, 8.0	High: 10.0 Low: 6.0
6	mmHg, 55	High: 70 Low: 40
7	kPa, 7.3	High: 9.3 Low: 5.3

Table 31

13, Pulse, adult
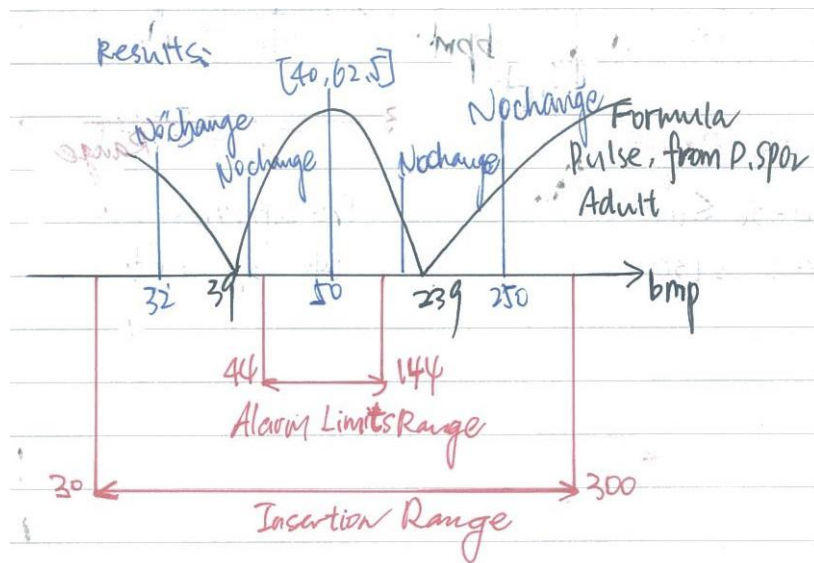
Figure 20

13.1, Endpoints that separate insertion and alarm limits ranges

Figure 21

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
bmp	30	44	144	300

Table 32

If pulse source is modified to be "from M.SpO2" or "from NBP", the upper and lower bound of the alarm limits range will not change.

Figure 22

13.2, Recommended test cases

Although the formula range may be different on choosing different sources, formula range is not the main focus in this test plan.

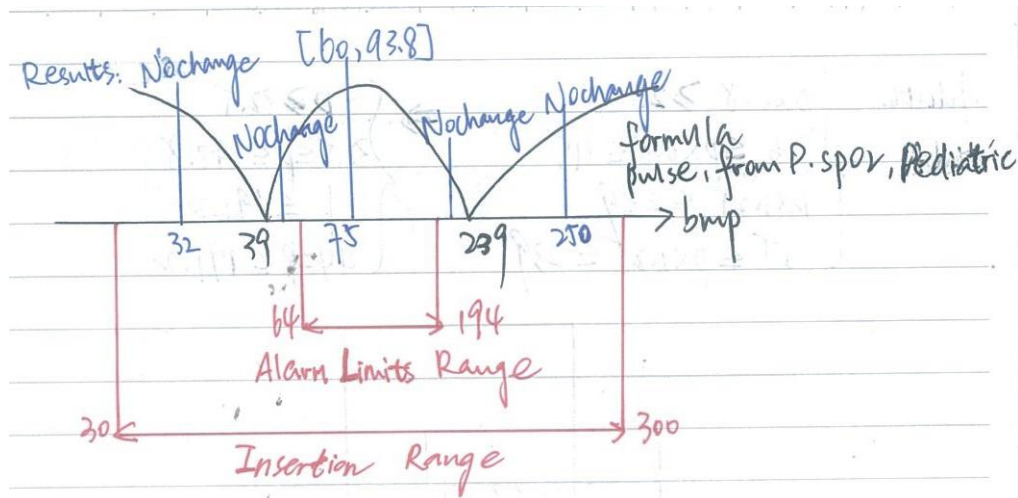| Case NO	Content (Pulse, adult)	Acceptance Criteria
1	<from all sources>, 29 <from all sources>, 301	Out of insertion range
2	<from all sources>, 30 <from all sources>, 300 <from all sources>, 39 <from all sources>, 239 <from all sources>, 43 <from all sources>, 144	High: No change Low: No change
4	! <from NBP>, 44	High: 55 Low: 35
5	<from all sources>, 143	High: 179 Low: 114
6	from NBP, 44	High: 55 Low: 41

Table 33

14, Pulse, pediatric

Figure 23

13.1, Endpoints that separate insertion and alarm limits ranges

Figure 24

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
bmp	30	64	194	300

Table 34

13.2, Recommended test cases

Case NO	Content (Pulse, pediatric)	Acceptance Criteria

1	<from all sources>, 29 <from all sources>, 301	Out of insertion range
2	<from all sources>, 30 <from all sources>, 300 <from all sources>, 39 <from all sources>, 239 <from all sources>, 63 <from all sources>, 194	High: No change Low: No change
4	<from all sources>, 64	High: 80 Low: 51
5	from P.SpO2, 193	High: 241 Low: 154
6	from M.SpO2, 193	High: 239 Low: 154
7	from NBP, 193	High: 239 Low: 154

Table 35

15, Pulse, neonatal

Figure 25

15.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
bmp	30	N/A	N/A	300

Table 36

15.2, Endpoints that separate formula ranges

Unit	Low / high limits	Formula range 1	Formula range 2
bmp	Low	110	130
bmp	High	140	170

Table 37

15.3, Recommended test cases

Case NO	Content (Pulse, neonatal)	Acceptance Criteria
1	<from all sources>, 29 <from all sources>, 301	Out of insertion range
2	<from all sources>, 100 <from all sources>, 110	High: 180 Low: 80
4	<from all sources>, 120	High: 180 Low: 90
5	<from all sources>, 130 <from all sources>, 140	High: 180 Low: 100
7	<from all sources>, 150	High: 190 Low: 100
8	<from all sources>, 170	High: 210 Low: 100
9	<from all sources>, 180	High: 210 Low: 100

Table 38

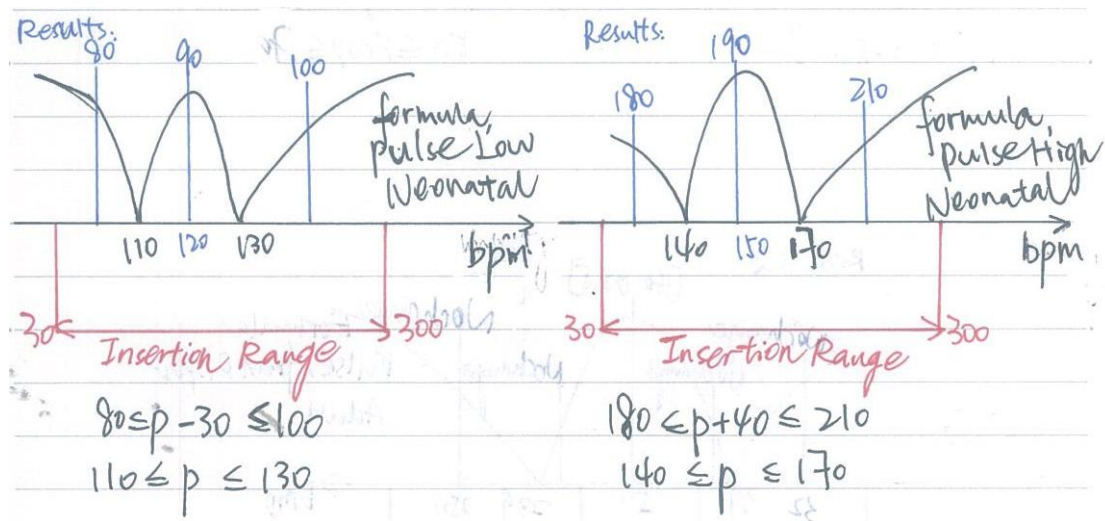## 16, Resp, !neonatal
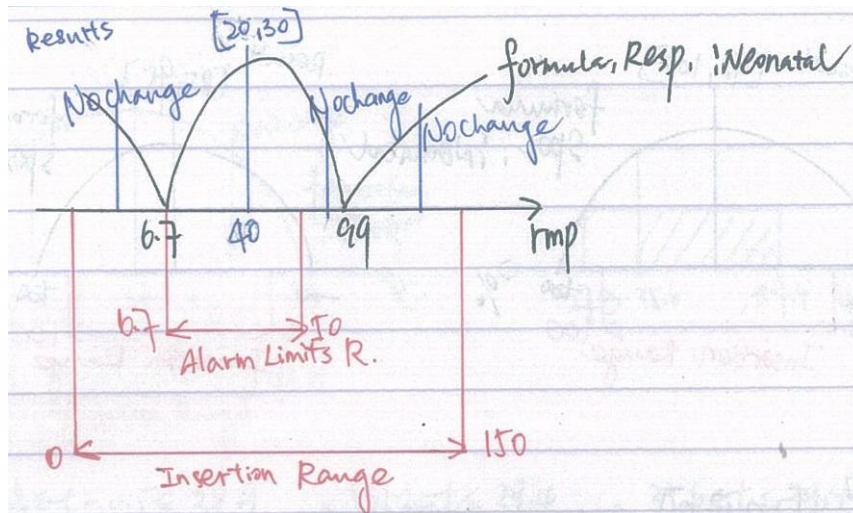
Figure 26

16.1, Endpoints that separate insertion and alarm limits ranges

Figure 27

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
rmp	0	7	50	150

Table 39

No matter the resp source is "from RRa" or "from awRR", the upper and lower bound of the alarm limits range will not change. In addition, the factory default of alarm settings are identical for adult and

pediatric patients.

16.2, Recommended test cases

Case NO	Content (Resp, !neonatal)	Acceptance Criteria
1	<from all sources>, !<neonatal>, 151	Out of insertion range
2	<from all sources>, !<neonatal>, 0 <from all sources>, !<neonatal>, 6 <from all sources>, !<neonatal>, 51	High: No change Low: No change
3	<from all sources>, !<neonatal>, 7	High: 11 Low: 4
4	<from all sources>, !<neonatal>, 40	High: 30 Low: 20
5	<from all sources>, !<neonatal>, 51	High: 30 Low: 25

Table 40

17, Resp, neonatal
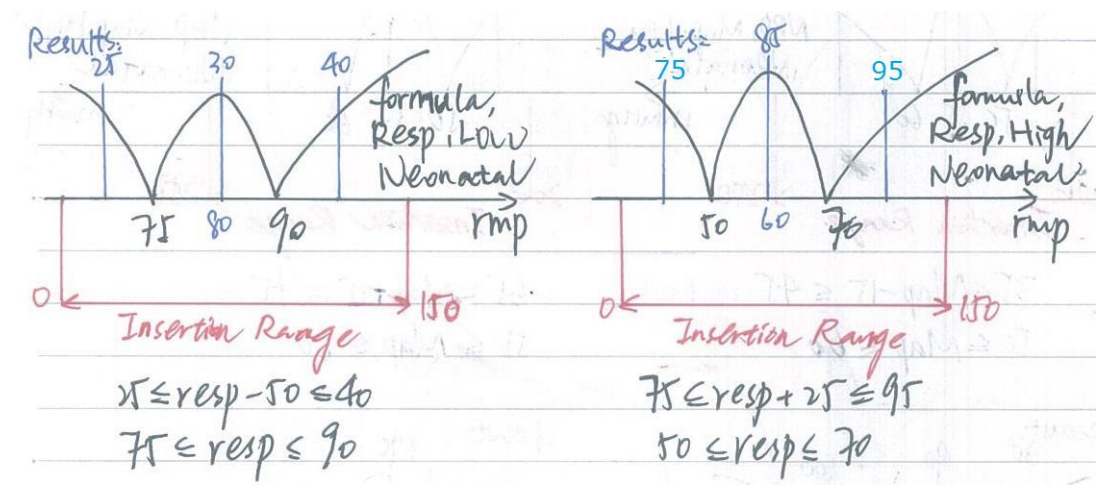
Figure 28

17.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
bmp	0	N/A	N/A	150

Table 41

17.2, Endpoints that separate formula ranges

Unit	Low / high limits	Formula range 1	Formula range 2
bmp	Low	75	90
bmp	High	50	70

Table 42

17.3, Recommended test cases

Case NO	Content (Resp, neonatal)	Acceptance Criteria
1	from awRR, neonatal, 151	Out of insertion range
2	from awRR, neonatal, 0 from awRR, neonatal, 50	High: 75 Low: 25
4	from awRR, neonatal, 70 from awRR, neonatal, 75	High: 95 Low: 25
5	from awRR, neonatal, 80	High: 95 Low: 30
6	from awRR, neonatal, 90	High: 95

|	from awRR, neonatal, 100	Low: 40
7	from RRa, neonatal	Unsupported Combination

Table 43

18, SpO2

Figure 29

18.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
%	0	N/A	N/A	100

Table 44

18.2, Recommended test cases

Case NO	Content (SpO2)	Acceptance Criteria
1	Spo2, !neonatal, 101 Spo2, neonatal, 101	Out of insertion range
2	Spo2, !neonatal, 0	High: 100

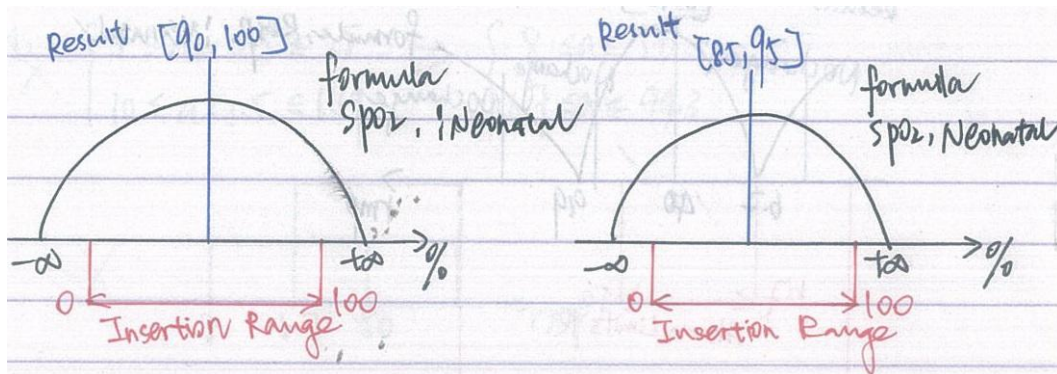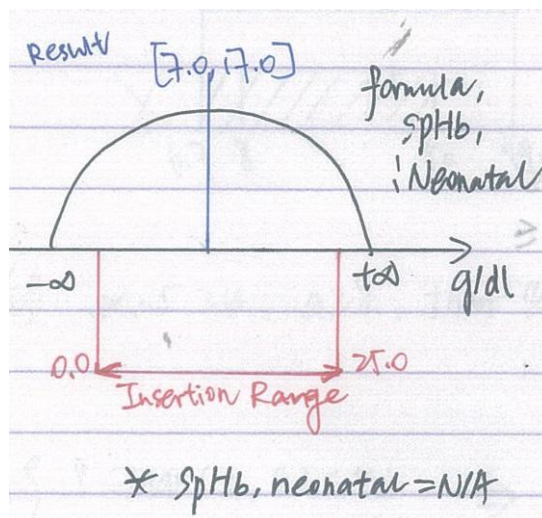|		
	Spo2, !neonatal, 50	Low: 90
	Spo2, !neonatal, 100	
3	Spo2, neonatal, 0	High: 95
	Spo2, neonatal, 50	Low: 85
	Spo2, neonatal, 100	

Table 45

19, SpHb

Figure 30

19.1, Endpoints that separate insertion and alarm limits ranges

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
g/dL	0.0	N/A	N/A	25.0
mmol/L	0.0	N/A	N/A	15.5

Table 46

19.2, Recommended test cases

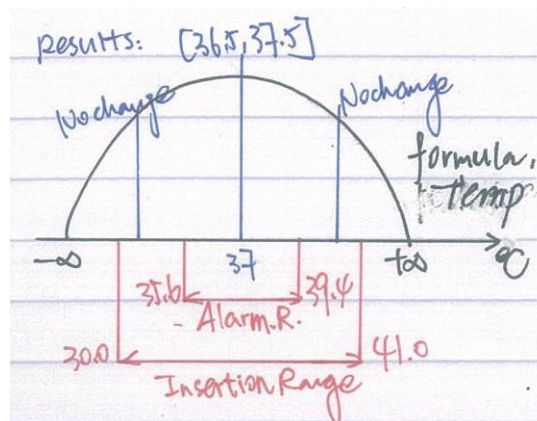| Case NO	Content (SpHb)	Acceptance Criteria
1	SpHb, !neonatal, g/dL, 25.1 SpHb, !neonatal, mmol/L, 15.6	Out of insertion range
2	SpHb, !neonatal, g/dL, 0 SpHb, !neonatal, g/dL, 12.0 SpHb, !neonatal, g/dL, 25.0	High: 17.0 Low: 7.0
3	SpHb, !neonatal, mmol/L, 0 SpHb, !neonatal, mmol/L,12.0 SpHb, !neonatal, mmol/L, 15.5	High: 10.6 Low: 4.3
4	SpHb, neonatal	Unsupported Combination

Table 47

20, Temp

Figure 31

20.1, Endpoints that separate insertion and alarm limits ranges

$$\begin{cases} 16.1 \leq t-0.5 \leq 38.9 \\ 36.1 \leq t+0.5 \leq 42.9 \end{cases} \Rightarrow \begin{cases} 16.6 \leq t \leq 39.4 \\ 35.6 \leq t \leq 42.4 \end{cases} \Rightarrow 35.6 \leq t \leq 39.4$$

Figure 32: Temp-E module (the same as Temporal Cradle module)

$$\begin{cases} 26.8 \leq t-0.5 \leq 38.9 \\ 36.1 \leq t+0.5 \leq 43.2 \end{cases} \Rightarrow \begin{cases} 27.3 \leq t \leq 39.4 \\ 35.6 \leq t \leq 42.7 \end{cases} \Rightarrow 35.6 \leq t \leq 39.4$$

Figure 33: Temp-P module

$$\begin{cases} 33.1 \leq t-0.5 \leq 38.9 \\ 36.1 \leq t+0.5 \leq 41.9 \end{cases} \Rightarrow \begin{cases} 33.6 \leq t \leq 39.4 \\ 35.6 \leq t \leq 41.4 \end{cases} \Rightarrow 35.6 \leq t \leq 39.4$$
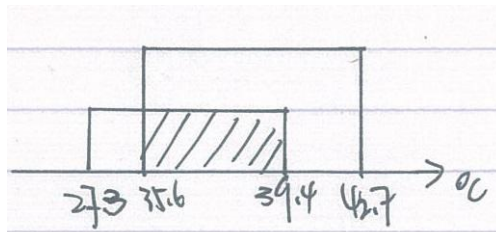
Figure 34: Temp-T module

Figure 35

Unit	Insertion (left)	Alarm (left)	Alarm (right)	Insertion (right)
C	30.0	35.6	39.4	41.0
F	86.0	96.1	102.9	105.8

Table 48

For all temp modules and all patient types, the above in-equations will render the same result.

20.2, Recommended test cases

Case NO	Content (Temp)	Acceptance Criteria
1	<all temp modules>, <all patient types>, C, 29.9 <all temp modules>, <all patient types>, C, 41.1 <all temp modules>, <all patient types>, F, 85.9 <all temp modules>, <all patient types>, F, 105.9	Out of insertion range
2	<all temp modules>, <all patient types>, C, 30.0 / 35.5 <all temp modules>, <all patient types>, C, 41.0 / 39.5 <all temp modules>, <all patient types>, F, 86.0 / 96.0 <all temp modules>, <all patient types>, F, 105.8 / 103.0	High: No change Low: No change
3	<all temp modules>, <all patient types>, C, 35.6	High: 36.1 Low: 35.1
4	<all temp modules>, <all patient types>, C, 39.4	High: 39.9 Low: 38.9
5	<all temp modules>, <all patient types>, F, 96.1	High: 97.0 Low: 95.2
6	<all temp modules>, <all patient types>, F,	High: 103.8

102.9		Low: 102.0

Table 49

F, Test results

The above test cases are 100% passed.

G, Future enhancement

The design and display of index page can be enhanced.

H, Appendix: factory defaults, alarm ranges and formulas

Factory Default Alarm Limits and Alarm Ranges

This section lists the default alarm limits and the alarm limit ranges for all physiological alarms.

Factory Default Alarm Limits

The following table lists the default alarm limits that are set in the factory.

Note — *Your system administrator can change these factory defaults to different default values.*

	Adult		Pediatric		Neonatal	
	High	**Low**	**High**	**Low**	**High**	**Low**
etCO2	60 mmHg (8.0 kPa)	25 mmHg (3.3 kPa)	60 mmHg (8.0 kPa)	25 mmHg (3.3 kPa)	60 mmHg (8.0 kPa)	25 mmHg (3.3 kPa)
imCO2	4 mmHg (0.5 kPa)	NA	4 mmHg (0.5 kPa)	NA	4 mmHg (0.5 kPa)	NA
IPI	NA	3	NA	NA	NA	NA
NBP Diastolic	90 mmHg (12.0 kPa)	50 mmHg (6.7 kPa)	70 mmHg (9.3 kPa)	40 mmHg (5.3 kPa)	60 mmHg (8.0 kPa)	20 mmHg (2.7 kPa)
NBP Mean	110 mmHg (14.7 kPa)	70 mmHg (9.3 kPa)	90 mmHg (12.0 kPa)	50 mmHg (6.7 kPa)	70 mmHg (9.3 kPa)	24 mmHg (3.2 kPa)
NBP Systolic	160 mmHg (21.3 kPa)	90 mmHg (12.0 kPa)	120 mmHg (16.0 kPa)	70 mmHg (9.3 kPa)	90 mmHg (12.0 kPa)	40 mmHg (5.3 kPa)
Pulse Rate	120 bpm	50 bpm	160 bpm	75 bpm	200 bpm	100 bpm
Respiration (CO2)	30 rpm	8 rpm	30 rpm	8 rpm	100 rpm	30 rpm
SpO$_2$	100%	90%	100%	90%	95%	85%
Temperature	39°C (102.2°F)	36°C (96.8°F)	39°C (102.2°F)	36°C (96.8°F)	39°C (102.2°F)	36°C (96.8°F)

Alarm Limit Ranges

The following table lists the user–adjustable ranges for all physiological alarms.

	Adult	Pediatric	Neonatal
etCO$_2$ High	32 mmHg – 149 mmHg (4.3 kPa – 19.9 kPa)	32 mmHg – 149 mmHg (4.3 kPa – 19.9 kPa)	32 mmHg – 149 mmHg (4.3 kPa – 19.9 kPa)
etCO$_2$ Low	1 mmHg – 70 mmHg (0.1 kPa – 9.3 kPa)	1 mmHg – 75 mmHg (0.1 kPa – 10 kPa)	1 mmHg – 75 mmHg (0.1 kPa – 10 kPa)
imCO$_2$ High	2 mmHg – 20 mmHg (0.3 kPa – 2.7 kPa)	2 mmHg – 20 mmHg (0.3 kPa – 2.7 kPa)	2 mmHg – 20 mmHg (0.3 kPa – 2.7 kPa)
imCO$_2$ Low	NA	NA	NA
IPI	1 – 9	NA	NA
NBP Diastolic High	55 mmHg – 244 mmHg (7.3 kPa – 32.5 kPa)	55 mmHg – 149 mmHg (7.3 kPa – 19.9 kPa)	22 mmHg – 99 mmHg (2.9 kPa – 13.2 kPa)
NBP Diastolic Low	11 mmHg – 85 mmHg (1.5 kPa – 11.3 kPa)	11 mmHg – 65 mmHg (1.5 kPa – 8.7 kPa)	11 mmHg – 55 mmHg (1.5 kPa – 7.3 kPa)
NBP Mean High	65 mmHg – 254 mmHg (8.7 kPa – 33.9 kPa)	55 mmHg – 159 mmHg (7.3 kPa – 21.2 kPa)	26 mmHg – 119 mmHg (3.5 kPa – 15.9 kPa)
NBP Mean Low	21 mmHg – 105 mmHg (2.8 kPa – 14.0 kPa)	21 mmHg – 85 mmHg (2.8 kPa – 11.3 kPa)	21 mmHg – 65 mmHg (2.8 kPa – 8.7 kPa)
NBP Systolic High	95 mmHg – 269 mmHg (12.7 kPa – 35.9 kPa)	75 mmHg – 179 mmHg (10.0 kPa – 23.9 kPa)	45 mmHg – 129 mmHg (6.0 kPa – 17.2 kPa)
NBP Systolic Low	31 mmHg – 155 mmHg (4.1 kPa – 20.7 kPa)	31 mmHg – 120 mmHg (4.1 kPa – 16.0 kPa)	31 mmHg – 85 mmHg (4.1 kPa – 11.3 kPa)

	Adult	Pediatric	Neonatal
Predictive Temperature High	36.1°C − 43.2°C (97.0°F − 109.8°F)	36.1°C − 43.2°C (97.0°F − 109.8°F)	36.1°C − 43.2°C (97.0°F − 109.8°F)
Predictive Temperature Low	26.8°C − 38.9°C (80.2°F − 102.0°F)	26.8°C − 38.9°C (80.2°F − 102.0°F)	26.8°C − 38.9°C (80.2°F − 102.0°F)
Pulse Rate High (SpO2)	55 bpm − 299 bpm	80 bpm − 299 bpm	80 bpm − 299 bpm
Pulse Rate Low (SpO2)	31 bpm − 115 bpm	31 bpm − 155 bpm	31 bpm − 195 bpm
Pulse Rate High (NBP)	55 bpm − 239 bpm	80 bpm − 239 bpm	80 bpm − 239 bpm
Pulse Rate Low (NBP)	41 bpm − 115 bpm	41 bpm − 155 bpm	41 bpm − 195 bpm
SpO2 High	50% − 100%	50% − 100%	31% − 100%
SpO2 Low	0% − 99%	0% − 99%	0% − 99%
Temporal Temperature High	36.1°C − 42.9°C (97.0°F − 109.2°F)	36.1°C − 42.9°C (97.0°F − 109.2°F)	36.1°C − 42.9°C (97.0°F − 109.2°F)
Temporal Temperature Low	16.1°C − 38.9°C (61.0°F − 102.0°F)	16.1°C − 38.9°C (61.0°F − 102.0°F)	16.1°C − 38.9°C (61.0°F − 102.0°F)
Tympanic Temperature High	36.1°C − 41.9°C (97.0°F − 107.4°F)	36.1°C − 41.9°C (97.0°F − 107.4°F)	36.1°C − 41.9°C (97.0°F − 107.4°F)
Tympanic Temperature Low	33.1°C − 38.9°C (91.6°F − 102.0°F)	33.1°C − 38.9°C (91.6°F − 102.0°F)	33.1°C − 38.9°C (91.6°F − 102.0°F)

Auto Set Alarms

The following tables list the formulas used for calculating Auto Set Alarm Limits. The Auto Set Alarm Limits option is available in the **Alarm Menu**.

Adult/Pediatric Auto Set Alarm Calculations

Parameter	Adult/Pediatric Lower Limit	Adult/Pediatric Upper Limit
etCO2	• 0 mmHg − 32 mmHg (0 kPa − 4.3 kPa): No change • 32 mmHg − 35 mmHg (4.3 kPa − 4.7 kPa): 29 mmHg (3.9 kPa) • 35 mmHg − 45 mmHg (4.7 kPa − 6.0 kPa): etCO2 − 6 mmHg (etCO2 − 0.8 kPa) • 45 mmHg − 48 mmHg (6.0 kPa − 6.4 kPa): 39 mmHg (5.2 kPa) • > 48 mmHg (6.4 kPa): No change	• 0 mmHg − 32 mmHg (0 kPa − 4.3 kPa): No change • 32 mmHg − 35 mmHg (4.3 kPa − 4.7 kPa): 41 mmHg (5.5 kPa) • 35 mmHg − 45 mmHg (4.7 kPa − 6.0 kPa): etCO2 + 6 mmHg (etCO2 + 0.8 kPa) • 45 mmHg − 48 mmHg (6.0 kPa − 6.4 kPa): 51 mmHg (6.8 kPa) • > 48 mmHg (6.4 kPa): No change
imCO2 (inspired)	No change	20 mmHg (2.7 kPa)
IPI	Same as default alarm limit for Adult. Not supported on Pediatric patients.	Same as default alarm limit for Adult. Not supported on Pediatric patients.
NBP Diastolic	Diastolic x 0.68 mmHg + 6 mmHg Diastolic x 0.68 kPa + 0.8 kPa	Diastolic x 0.86 mmHg + 32 mmHg Diastolic x 0.86 kPa + 4.3 kPa
NBP Map	MAP x 0.68 mmHg + 8 mmHg MAP x 0.68 kPa + 1.1 kPa	MAP x 0.86 mmHg + 35 mmHg MAP x 0.86 kPa + 4.7 kPa
NBP Systolic	Systolic x 0.68 mmHg + 10 mmHg Systolic x 0.68 kPa + 1.3 kPa	Systolic x 0.86 mmHg + 38 mmHg Systolic x 0.86 kPa + 5.1 kPa

Parameter	Adult/Pediatric Lower Limit	Adult/Pediatric Upper Limit
Pulse Rate (NBP)	Pulse x 0.8 or 41/min (whichever is greater)	Pulse x 1.25 or 239/min (whichever is smaller)
Pulse Rate (SpO2)	Pulse x 0.8 or 31/min (whichever is greater)	Pulse x 1.25 or 299/min (whichever is smaller)
Respiration (CO2)	awRR x 0.5 or 4 rpm (whichever is greater)	awRR x 1.5 or 30 rpm (whichever is smaller)
SpO2	Same as default alarm limit	Same as default alarm limit
Temperature	Temp − 0.9°F Temp − 0.5°C	Temp + 0.9°F Temp + 0.5°C

Neonatal Auto Set Alarm Calculations

Parameter	Neonatal Lower Limit	Neonatal Upper Limit
etCO2	• 0 mmHg − 32 mmHg (0 kPa − 4.3 kPa): No change • 32 mmHg − 35 mmHg (4.3 kPa − 4.7 kPa): 29 mmHg (3.9 kPa) • 35 mmHg − 45 mmHg (4.7 kPa − 6.0 kPa): $etCO_2 − 6$ mmHg ($etCO_2 − 0.8$ kPa) • 45 mmHg − 48 mmHg (6.0 kPa − 6.4 kPa): 39 mmHg (5.2 kPa) • > 48 mmHg (6.4 kPa): No change	• 0 mmHg − 32 mmHg (0 kPa − 4.3 kPa): No change • 32 mmHg − 35 mmHg (4.3 kPa − 4.7 kPa): 41 mmHg (5.5 kPa) • 35 mmHg − 45 mmHg (4.7 kPa − 6.0 kPa): $etCO_2 + 6$ mmHg ($etCO_2 + 0.8$ kPa) • 45 mmHg − 48 mmHg (6.0 kPa − 6.4 kPa): 51 mmHg (6.8 kPa) • > 48 mmHg (6.4 kPa): No change
imCO2	No change	20 mmHg (2.7 kPa)
IPI	NA	NA
NBP Diastolic	Diastolic − 15 (within 20 mmHg − 40 mmHg) Diastolic − 2 within 2.7 kPa − 5.3 kPa	Diastolic + 15 (within 55 mmHg − 75 mmHg) Diastolic + 2 within 7.3 kPa − 10.0 kPa

Parameter	Neonatal Lower Limit	Neonatal Upper Limit
NBP Map	MAP − 15 (within 35 mmHg − 45 mmHg) MAP − 2 within 4.7 kPa − 6.0 kPa	MAP + 15 (within 65 mmHg − 75 mmHg) MAP + 2 within 8.7 kPa − 10.0 kPa
NBP Systolic	Systolic − 15 (within 45 mmHg − 60 mmHg) Systolic − 2 within 6.0 kPa − 8.0 kPa	Systolic + 15 (within 90 mmHg − 115 mmHg) Systolic + 2 within 12.0 kPa − 15.3 kPa
Pulse Rate (NBP)	Pulse − 30 (within 80 − 100/min)	Pulse + 40 (within 180 − 210/min)
Pulse Rate (SpO2)	Pulse − 30 (within 80 − 100/min)	Pulse + 40 (within 180 − 210/min)
Respiration (CO2)	awRR − 50 (within 25 − 40)	awRR + 25 (within 75 − 95)
SpO2	Same as default alarm limit	Same as default alarm limit
Temperature	Temp − 0.9°F Temp − 0.5°C	Temp + 0.9°F Temp + 0.5°C