Non-Cardiopulmonary Monitoring in Thai-ICU (ICU-RESOURCE I Study)

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Objective: *In addition to cardiopulmonary monitoring, non-cardiopulmonary monitoring (non-CPM) is considered to be an important parameter in intensive care units (ICUs). However, no data on this subject has been reported for Thai ICUs. The objective of the present study is to describe the non-CPM situation in Thai ICUs.*

Materials and Method: *ICU RESOURCE I survey database released during the year 2012 was used for the present study. Non-CPMo refers to neurological monitoring, renal function monitoring, metabolic monitoring, perfusion monitoring and identifying biomarkers. Academic hospital (ACAD), availability grading (AG), numeric frequency grading scale (FGS) and device availability per bed (DPB) were used for categorization of non-CPM collected data. Significant differences between the groups are defined as $p<0.05$.*

Results: *Advanced monitoring, including; indirect calorimetry, near infrared spectroscopy, peripheral nerve stimulation, gut mucosal tonometry and sublingual side stream dark field imaging are currently unavailable in participating Thai ICUs. All ICUs have devices to measure the levels of capillary glucose, creatinine kinase MB, troponin T and albumin. Bispectral index, ultrasound, continuous renal replacement therapy devices, continuous enteral feeding pumps, intra-abdominal pressure monitoring devices and rectal temperature measuring devices are available in ACAD facilities in greater instances than in other institutions. Similarly; for biomarker and drug level monitoring; procalcitonin, interleukin, brain natriuretic peptide, total creatinine kinase, neutrophilgelatinase-associated lipocalin (NGAL), lactate, central venous oxygen saturation/mixed venous oxygen saturation ($ScvO_2/SvO_2$), phenytoin, vancomycin and pre-albumin are used more frequently in ACADs. Gap analysis demonstrating warmer cabins, NGAL, lactate and $ScvO_2/SvO_2$ show less availability but are frequently used when they have been made available. Intra-abdominal pressure and core temperatures are used less in general ICU practices and are scarcely found.*

Conclusion: *Some of the more advanced non-CPM devices are not found in Thai ICUs. Basic non-CPM devices are available in all ICUs. Some new devices for measurements and for biomarkers are used with greater prevalence in ACAD ICUs. Some measurements including IAP, core temperature, lactate and $ScvO_2/SvO_2$) are monitored less frequently in Thai ICUs (Thai Clinical Trial Registry: TCTR-201200005).*

Keywords: *Non-cardiopulmonary monitoring, Thai, Intensive care unit, Utilization gap, Frequency level, Device availability*

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Critically ill patients require multi-modal monitoring systems for obtaining information regarding physiologic alterations. In addition to cardiopulmonary monitoring, non-cardiopulmonary monitoring (non-CPM) also plays an important role. The non-CPM is composed of neurological, nephrological, metabolic, perfusion and biomarker monitoring[1-7]. As a result of the high costs of some specific devices and tests, some particular non-CPM might not be available in the ICUs. There have been no previous reports regarding the availability and utilization of non-CPM in Thai ICUs. The aim of the present study is to describe the information regarding non-CPM in Thai ICUs.

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Material and Method

The data were retrieved from the ICU RESOURCE I study survey database. The survey period was between March 1st and August 31st, 2012. The details of non-cardio-pulmonary monitoring, including; neurological monitoring, monitoring renal function,

metabolic monitoring devices, perfusion and biomarker monitoring were recorded. The information regarding study planning was registered with Thai Clinical Trial Registry. The reference number designated is TCTR-201200005. The present study is approved by the Ethics Committee, Chiang Mai University.

The definition of hospital types, academic hospital (ACAD), availability grading (AG), numeric frequency grading scale (FGS) and device availability per bed (DPB) were the same as determined by the study of the cardio-pulmonary study (CPMo) in Thai ICUs which was previously reported by this same study group[8]. Details of devices are shown in Table 1. All data were analyzed by STATA (version 11.0, STATA Inc., College Station, TX). The parametric and non-parametric continuous variables of the two groups were evaluated by t-test (mean $\pm$ standard deviation [SD]) and the Wilcoxon rank sum (median; interquartile range [IQR]). Categorized data of the differences of the two groups were analyzed by Pearson' Chi-square. Significant differences are defined as $p<0.05$. Gap analysis was performed for the density, availability and frequency levels.

Results

One hundred fifty-five Thai ICUs from all regions are included in the present study. Most of the participating ICUs are in government hospitals

Table 1. Non-CPMo equipments, devices, monitoring and biomarkers categorized by ICU types

Equipments, devices and monitors	All n = 155	Non-ACAD n = 119	ACAD n = 36	p-value
Bispectral index (BIS)	2 (1.29)	0 (0.00)	2 (5.56)	0.010
Fluid warmer cabin (Warmer)	16 (10.32)	12 (10.08)	4 (11.11)	0.859
Indirect calorimetry	NA	NA	NA	NA
Ultrasound (US)	53 (34.19)	35 (29.41)	18 (50.00)	0.023
Near infrared spectroscopy (NIS)	NA	NA	NA	NA
Peripheral nerve stimulation and train of four (PNS)	NA	NA	NA	NA
Gut mucosal tonometry (GMT)	NA	NA	NA	NA
Intra-abdominal pressure monitor devices (IAPmo)	8 (5.16)	4 (3.36)	4 (11.11)	0.066
Esophageal temperature measuring device (E-temp)	6 (3.87)	3 (2.52)	3 (8.33)	0.113
Rectal temperature measuring device (R-temp)	35 (22.58)	23 (19.33)	12 (33.33)	0.078
Continuous renal replacement therapy device (CRRT)	29 (18.71)	11 (9.24)	18 (50.00)	<0.001
Hemodialysis devices (HD)	42 (27.10)	29 (24.37)	13 (36.11)	0.165
Capillary glucose devices (CGD)	155 (100)	119 (100)	36 (100)	NA
Sublingual side stream dark field (SDF)	NA	NA	NA	NA
Continuous enteral feeding pump (Feed-pump)	50 (32.26)	25 (21.01)	25 (69.44)	<0.001
Measurement methods				
Continuous Sjv O_2 monitoring ($SjvO_2$)	6 (3.87)	3 (2.52)	3 (8.33)	0.113
Intracranial pressure monitoring (ICP)	22 (14.19)	14 (11.76)	8 (22.22)	0.115
Intraabdominal pressure (IAP)	19 (12.26)	8 (6.72)	11 (30.56)	<0.001
ICU Markers				
Creatinine kinase MB (CK-MB)	155 (100)	119 (100)	36 (100)	NA
Troponin T (Trop-T)	155 (100)	119 (100)	36 (100)	NA
Procalcitonin (Procal)	28 (18.06)	11 (9.24)	17 (47.22)	<0.001
BNP (cardiogenic marker)	51 (32.90)	29 (24.37)	22 (61.11)	<0.001
Neutrophil gelatinase-associated lipocalin (NGAL)	16 (10.32)	7 (5.88)	9 (25.00)	0.001
Interleukin (IL)	10 (6.45)	1 (0.84)	9 (25.00)	<0.001
Lactate	75 (48.39)	44 (36.97)	31 (86.11)	<0.001
Cortisol	100 (64.52)	72 (60.50)	28 (77.78)	0.058
Phenytoin level (Pheny)	94 (60.65)	64 (53.78)	30 (83.33)	0.001
Vancomycin level (Vanco)	40 (25.81)	15 (12.61)	25 (69.44)	<0.001
Albumin (Alb)	155 (100)	119 (100)	36 (100)	NA
Proalbumin (Proalb)	12 (7.74)	2 (1.68)	10 (27.78)	<0.001
Blood $ScvO_2$ or SvO_2 ($ScvO_2$/SvO_2)	56 (36.13)	33 (27.73)	23 (63.89)	<0.001
Total creatinine kinase (CK)	64 (41.29)	41 (34.45)	23 (63.89)	0.002

(89.03%). In Table 1, indirect calorimetry, near infrared spectroscopy (NIS), peripheral nerve stimulation (PNS), gut mucosal tonometry (GMT) and sublingual side stream dark field imaging (SDF) are unavailable in participating Thai ICUs. All ICUs have capillary glucose devices (CGD) and are able to investigate basic ICU markers including creatinine kinase MB (CK-MB), troponin T (Trop-T) and albumin levels (Alb).

ACAD ICUs have a significantly higher availability of advanced monitoring devices ($p<0.05$; Table 1). These consist of bispectral index (BIS), ultrasound (US), continuous renal replacement therapy devices (CRRT) and continuous enteral feeding pumps (Feed-pump). In spite of a higher availability of intra-abdominal pressure monitoring devices (IAPmo) and rectal temperature measuring devices (R-temp) in the ACADs, there are no significant differences in frequency of use ($p<0.10$; Table 1). However, intra-abdominal pressure measurement (IAP) is performed more frequently in ACAD ICUs (30.56% vs. 6.72%; $p<0.001$; Table 1). There are no differences in the availability of intermittent hemodialysis devices (HD) between the groups. As for measurement methods, although continuous jugular venous oxygen saturation ($SjvO_2$) monitoring and intracranial pressure monitoring (ICP) is more readily available in ACAD ICUs, there were no differences in the usages of the tests.

Advanced ICU markers including inflammatory or infectious markers (Procalcitonin [Procal], interleukin [IL]), cardiogenic markers (brain natriuretic peptide [BNP], total creatinine kinase [CK]), renal injury markers (neutrophil gelatinase-associated lipocalin [NGAL]), peripheral perfusion markers (lactate, $ScvO_2$ or SvO_2), drug monitoring (phenytoin [pheny], vancomycin [vanco]), nutritional markers (pre-albumin) show a significantly higher availability in ACAD ICUs than non-ACAD ICUs. Despite the higher availability of cortisol level measuring devices in ACAD ICUs, there was merely a slight trend in its regular use (77.78% vs. 60.50%; $p = 0.058$, Table 1).

As for specific organ monitoring; BIS, $SjvO_2$ and ICP were classified as "rarely", "few available", and "sometimes used", respectively for use in neurological monitoring (Table 2-4). Core temperatures were not regularly monitored. If it was a consideration, the rectal route would be used more frequently than the esophageal route. Although there are not many available, warmer cabin devices with a low density were frequently used in ICUs. Intra-abdominal pressure monitoring devices are rarely available with low density per bed institutions and not regularly used. In regards to renal monitoring and treatment devices, HD is more available than CRRT. Although NGAL is a test that is rarely available, it is frequently used in ICUs when they are available. Regarding inflammatory biomarkers, both IL and procalcitonin are less commonly available and assays are used with less frequency in Thai ICUs. Other biomarkers (BNP, Lactate, Vanco, CK, $ScvO_2$, SvO_2, Cortisol, Phenytoin level) are moderately to commonly available and most of them are measured with regularity. Interestingly, feeding pumps are of medium density per bed in available ICUs but they are used constantly in ICUs.

As for the gap analysis in Table 4, warmer cabin temperatures, NGAL demonstrates rare and few available devices that are used regularly. Despite the moderate availability of some resuscitation target assays including lactate and $ScvO_2/SvO_2$, they show only irregular use.

Discussion

Non-CPMos play an important role in ICUs. Unfortunately, there is no information regarding the availability and utilization of non-CPMos in Thai ICUs.

Table 2. Monitoring, device and measurement method categorized by availability grading in Thai ICUs

Availability grade	Devices	Measurements	Markers
None (0%)	Indirect calorimetry, NIS, PNS, GMT, SDF		
Rarely (<10%)	BIS, IAP-Mo, E-temp	$SjvO_2$	*NGAL, IL*
Few (10-19.9%)	Warmer, CRRT	ICP, IAP	*Procal*
Moderate (20-49.9%)	US, R-temp, HD, Feed-pump		*BNP, Lactate, Vanco, CK, $ScvO_2$, SvO_2*
Common (50-79.9%)			*Cortisol, Pheny*
Abundance (>80%)	CGD		*CK-MB, Trop-T, Alb*

Note: *Italic* words were biomarkers

Table 3. Monitoring, device and measurement method categorized by median of frequency level in available ICUs

Frequency level	Devices	Measurements	Markers
Never (FGS = 0)	Indirect calorimetry, NIS, PNS, GMT, SDF		*IL, Prealb*
Sometimes (FGS <3)	BIS, US, IAP-mo, E-temp, R-temp, CRRT, HD	$SjvO_2$, ICP, IAP	*Procal, BNP, Lactate, Cortisol, Pheny, Vanco, $ScvO_2$, SvO_2*
Usually (FGS 4-5)	Warmer		*CK-MB, Trop-T, NGAL, CK*
Always (FGS 6-7)	CGD, Feed-pump		*Alb*

Note: *Italic* words were biomarkers

Table 4. Monitoring, device and measurement methods categorized by median density level and frequency level in available ICUs

Density/Frequency	Sometime (FGS <3)	Usually (FGS 4-5)	Always (FGS 6-7)
Low density (DPB <0.3)	BIS, US, IAP-Mo, E-temp, R-temp, CRRT, HD	Warmer	-
Medium density (DPB 0.31-0.69)	-	-	CGD, Feed-pump
High density (DPB ≥0.70)	-	-	-
Availability level			
Rarely (<10%)	BIS, IAP-Mo, E-temp, *$SjvO_2$, IL*	*NGAL*	
Few (10-19.9%)	CRRT, *Procal, ICP, IAP*	Warmer	
Moderate (20-49.9%)	US, R-temp, HD, *BNP, Lactate, Vanco, $ScvO_2$/SvO_2*	*CK,*	Feed-pump
Common (50-79.9%)	*Cortisol, Pheny*		
Abundance (>80%)		*CK-MB, Trop-T,*	CGD, *Alb*

Note: *Italic* words were biomarkers

This study is a pioneer study surveying for the presence and the utilization of non-CPM in ICUs in Thailand. Basic, advanced and biomarker monitoring devices are included. Many newly advanced monitoring devices are not available in Thai ICUs (indirect calorimetry, NIS, PNS, GMT and SDF). Although indirect calorimetry has been reported as a device frequently used in ICUs[9,10], they were unavailable in participating ICUs. Rarely available devices for measurements and markers in Thai ICUs are: BIS, IAP-Mo, E-temp, Warmer, CRRT, $SjvO_2$, ICP, IAP, NGAL, IL and Procal (Table 1,2). Most of them show a higher availability in ACAD ICUs (Table 1). Basic devices and markers for CGD, CK-MB, Trop-T and Alb were readily obtainable in this survey.

Resuscitation target assays of lactate and $ScvO_2$/SvO_2 are recommended in the updated guidelines for severe sepsis management[11]. Despite both of them being considered common markers, they were found to be abundantly obtainable in ACAD (≥50%) and only rarely available (<50%) in non-ACAD ICUs (Table 3,4). These findings demonstrate an interesting point of pattern management differences and show an availability gap between ACAD and non-ACAD ICUs. Guideline recommendations should be propagated with continuous education to ICU health care providers.

IL is used as a marker to predict the severity of a disease and assess nutrition[3]. This is inferred to be a common biomarker in developed countries[3]. However, this biomarker is moderately available in ACAD and rarely available in non-ACAD ICUs and as a result, this marker is never used in Thai ICUs. NGAL had availability levels identical to IL in Thai ICUs and the purpose of this marker is for the early identification of kidney injury[4]. Contrarily, NGAL is usually available and more frequently used. These findings imply that NGAL will have higher tendency to be considered the monitoring marker of the future. In spite of procalcitonin and BNP showing only "few to moderate" availability in all ICUs (<50%), the frequency of the use of these

markers is limited.

Considering drug and hormone monitoring, cortisol and phenytoin levels are commonly obtainable in Thai ICUs. Vancomycin measuring was available in only a few ICUs surveyed. However, all of them were used in the "sometimes" level when drug monitoring. These findings imply that it may require more consideration when monitoring for drugs and hormones in Thai critical care practices.

The incidence of intra-abdominal hypertension was reported at about 33% of patients on admission and a third were diagnosed during their stay in the ICU[2]. However, IAP-Mo and its measurement have shown only a "low density" and have only a few available in Thai ICUs (Table 2-4). In addition, these are only utilized some of the time (FGS <3). This evidence indicates that there are few concerns regarding intra-abdominal hypertension in general ICU practice.

Rectal and esophageal temperatures were obtained by non-invasive methods and demonstrate the most accurate range of agreement for core temperature measurement when compared to invasive methods[12,13]. However, these were obtainable with less density (E-temp <10%, R-temp <20%). These findings demonstrate that core temperature measurement is not routinely used and most temperature chart records are possibly measured by superficial modes such as axillary or inguinal methods which are less accurate when compared to invasive core temperature measurements. Interestingly, in spite of regular use, warmer cabin or other devices are not readily available and are of "low density" in Thai ICUs (<20%).

Both CRRT and intermittent hemodialysis (HD) have been widely used in ICUs during the last decade[14,15]. In this survey, HD was not significantly different in regard to availability between ACAD and non-ACAD facilities. ACAD had more availability of CRRT. The availability of renal replacement therapy in all Thai ICUs is of "low density" and is less obtainable.

As for neurological monitoring, BIS could be found only in ACAD ICUs. EEGs were excluded from this survey because of questionnaire inaccuracies. ICP was the only monitoring used in a few of the ICUs as was $SjvO_2$. This was obtainable as a neurological perfusion parameter of less than 10% (ACAD 8.33% vs. non-ACAD 2.52%; p = 0.165; Table 1).

There were several limitations in this study. First, the participating ICUs were not random and there was an unequal proportion of each hospital type. Selection bias might be a consideration. Second, utilization evaluation by frequency of device use or measurement may be inaccurate. These could be confounded by alternative methods, particularly in regard to clinical evaluation which is not mentioned or included in this survey. These are evitable limitations; however, this study demonstrates the situation of non-CPMo in Thai ICUs as well as their availability and utilization.

Conclusion

Some advanced non-CPMo is not found in Thai ICUs. Basic non-CPMo (CGD, CK-MB, Trop-T and Alb) are available in all ICUs. Some new devices, measurements and biomarkers can be obtained only in ACAD ICUs. Some measurements (IAP, core temperature, lactate, $ScvO_2/SvO_2$) have shown less consideration for in Thai ICUs.

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Potential conflicts of interest

None.

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การสำรวจเครื่องมือการติดตามนอกเหนือจากระบบไหลเวียนและการหายใจในประเทศไทย (ICU-RESOURCE I study)

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วัตถุประสงค์: นอกเหนือจากการติดตามระบบการไหลเวียนและการหายใจแล้ว การติดตามในระบบอื่น ๆ นอกเหนือจากระบบดังกล่าวก็มีความสำคัญในไอซียู อย่างไรก็ตามไม่มีข้อมูลดังกล่าวรายงานในไอซียูไทย วัตถุประสงค์ของการศึกษานี้เพื่อบรรยายสถานการณ์การใช้เครื่องมือการติดตามนอกเหนือจากระบบไหลเวียนและการหายใจในประเทศไทย

วัสดุและวิธีการ: ข้อมูลในการศึกษานี้นำมาจากฐานข้อมูล ICU RESOURCE I ในปี พ.ศ. 2555 เครื่องมือดังกล่าวได้แก่ การติดตามในระบบสมอง ไต เมตาบอลิสต์ ความกำซาบของเลือดส่วนปลายและตัวบ่งชี้ทางชีววิทยา โดยเก็บข้อมูลเกี่ยวกับชนิดของไอซียู ความสามารถในการเสาะหา (availability grading, AG) ความถี่ของเครื่องมือต่อเตียง (device availability per bed, DPB) และจำนวนความถี่ของการใช้งาน (frequency grading scale, FGS) และใช้ค่าดังกล่าวเพื่อการจำแนกกลุ่มของเครื่องมือและการวัดต่าง ๆ โดยความแตกต่างอย่างมีนัยสำคัญทางสถิติเมื่อ $p<0.05$

ผลการศึกษา: เครื่องติดตามที่ทันสมัย เช่น indirect calorimetry, near infrared spectroscopy, peripheral nerve stimulation, gut mucosal tonometry และ sublingual side stream dark field พบว่าไม่มีเครื่องมือดังกล่าวในไอซียูที่เข้าร่วม ทุกไอซียูมีเครื่องวัดน้ำตาลปลายนิ้ว creatinine kinase MB, troponin T และ albumin เครื่องมือหลายอย่างสามารถหาได้เฉพาะไอซียูในสถาบันฝึกอบรมเป็นส่วนใหญ่ ได้แก่ เครื่องวัดคลื่นไฟฟ้าสมอง, อัลตร้าซาวด์, เครื่องไตเทียมที่ใช้อย่างต่อเนื่อง เครื่องให้อาหารอย่างต่อเนื่อง, เครื่องวัดความดันในช่องท้องและการวัดอุณหภูมิจากทวารหนัก สำหรับตัวชี้วัดทางชีววิทยาและระดับยาก็มีทิศทางเดียวกัน ได้แก่ procalcitonin, Interleukin, brain natriuretic peptide, total creatinine kinase, neutrophil gelatinase-associated lipocalin (NGAL), lactate, $ScvO_2/SvO_2$, phenytoin, vancomycin และ pre-albumin การวิเคราะห์ช่องว่างการใช้และความสามารถในการเสาะหา พบว่าเครื่องอุ่นสารน้ำ NGAL, lactate และ $ScvO_2/SvO_2$ มีความสัมพันธ์ระหว่างการใช้และความสามารถในการเสาะหา สำหรับการวัดความดันในช่องท้องและการวัดอุณหภูมิแกนกลางของร่างกายมีการใช้น้อยในเวชปฏิบัติในไอซียู

สรุป: เครื่องมือติดตามนอกเหนือจากระบบการไหลเวียนและการหายใจที่ทันสมัยบางอย่างไม่พบในไอซียูของไทย ในการศึกษานี้การติดตามพื้นฐานหลายชนิดพบได้ในไอซียูทั้งหมดของไทย เครื่องมือใหม่และการวัดรวมถึงตัวชี้วัดหลายอย่างพบเป็นส่วนใหญ่ในสถาบันฝึกอบรม การวัดบางอย่าง เช่น การวัดความดันในช่องท้อง อุณหภูมิแกนกลาง lactate และ $ScvO_2/SvO_2$ มีการใช้น้อยในไอซียูไทย