Evaluation of Correlation between Vascular Pedicle Width and Intravascular Volume Status in Thai Critically Ill Patients

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Objective: *To evaluate the correlation between vascular pedicle widths (VPW) measured from portable chest roentgenogram (CXR) and intravascular volume status in Thai critically ill patients.*
Material and Method: *A prospective cohort study included the critically ill patients in whom pulmonary artery catheter was placed in the Medical Intensive Care Units of Siriraj Hospital, Mahidol University between June 2009 and January 2010. The patient's baseline characteristics, hemodynamic data measured from pulmonary artery catheter (PAC) and CXR parameters were collected.*
Results: *From thirty-four patients, thirteen (38.2%) had high pulmonary artery occlusive pressure (PAOP $\geq$18 mmHg). The patients with high PAOP were older (69.8 $\pm$ 8.8 years vs. 59.2 $\pm$ 15.4 years, p = 0.02), taller (163.2 $\pm$ 5.3 cm vs. 157.0 $\pm$ 10.4 cm, p = 0.03) and higher weight (67.4 $\pm$ 12.9 kg vs. 57.1 $\pm$ 7.8 kg, p = 0.007) than the low PAOP group. The correlations between PAOP and VPW (r = 0.68, p < 0.001) as well as between PAOP and cardiothoracic ratio (CTR) (r = 0.23, p = 0.03) were significant. From the receiver operating characteristic (ROC) curve, VPW > 68 mm is the best parameter to predict PAOP $\geq$ 18 mmHg (the area under the curve (AUC) = 0.853, p < 0.001, sensitivity = 92.3%, specificity = 85.7%). The CTR > 0.58 can be used to predict elevated PAOP $\geq$ 18 mmHg with acceptable sensitivity = 85.74% and specificity = 76.9% (AUC = 0.727, p = 0.03). The peribronchial cuffing (PBC) was detected at a higher percentage among high PAOP group than in the low PAOP group (76.9% vs. 33.3%, p = 0.03).*
Conclusion: *The VPW > 68 mm, CTR > 0.58 and the present of PBC can be used together to predict elevation of PAOP $\geq$ 18 mmHg among the Thai critically ill patients. By using these CXR parameters, the PAC insertion may be avoided especially in patients with contraindication.*

Keywords: *Intravascular volume, Chest x-ray, Vascular pedicle width critically ill patients, Cardiothoracic ratio, Pulmonary atery ccclusive pressure*

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Intravascular volume status assessment in critically ill patients is one of the most important issues, especially in shock management[1,2]. Various methods have been used to quantitate this condition, including central venous pressure (CVP), pulmonary artery occlusive pressure (PAOP) and echocardiography[3-6]. Although these maneuvers pose benefits, they also associate with certain risks and require specific skills[7-11]. The uses of plain-portable chest x-ray (CXR) as a bed-side tool to rectify the patients' volume status have been studied for years[12-16]. The measured parameter such as the vascular pedicle width (VPW) and cardiothoracic ratio (CTR) were reported as predictors for the PAOP level and the intravascular volume status with acceptable accuracy[15-18]. However, these studies were performed within Western countries.

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Considering the difference in body size, the cutoff point of CXR parameters to predict the elevation of PAOP may differ among the various ethnic patients.

To determine the usefulness of CXR in evaluation the patients' volume status, we designed this prospective cohort study to identify the correlation of CXR parameters and the patients' volume status and to identify the cutoff point of CXR parameters, including the VPW and CTR, for predicting the elevation of PAOP $\geq$ 18 mmHg among Thai critically ill patients.

Material and Method

Population

This prospective study included the patients who were admitted in a 12 bed Medical Intensive Care Unit of Siriraj Hospital, Bangkok Thailand, between June 2009 and January 2010. The patients aged over 18 year-old who had PA catheter inplace and agreed to sign the informed consent form were included to this study. Those who had history of previous cardiothoracic surgery, mediastinum disease, intrathoracic aortic aneurysm, valvular heart disease and chronic obstructive pulmonary disease were excluded from the study. The baseline characteristics, the hemodynamic parameters and the chest x-ray parameters were recorded. The hemodynamic parameters, including PAOP were recorded immediately after PA catheter insertion and the CXR were performed within 1 hour after hemodynamic parameters measurement.

CXR parameters measurement

For performing CXR, the patients were placed in the supine position. The Dynarad Portable unit, R72/37-E with the power of 80-85 k volts, 2.5-3.0 mAmp/s x-ray machine was used in this study. With the patients lying in supine position, the distance between the x-ray beam resource and the anterior chest wall of the patients was 40 inch.

The CXR parameters were obtained from the hospital's on line computer system. The VPW is the distance from an imaginary perpendicular line from the junction of superior vena cava shadow and the right main bronchus to an imaginary perpendicular line from the origin of subclavian artery and the arch of aorta. The CTR is the ratio of the maximum cardiac shadow width and the thoracic cage (Fig. 1). The peribronchial cuffing is the radio opaque density around the bronchial wall which relates to the thickening of the peribronchial soft tissue, bronchial wall and the epithelial lining inside the bronchus. The septal line is the radio opaque line in the lung parenchyma adjacent to the pleura. Air bronchogram is the radio lucent line with infiltration.

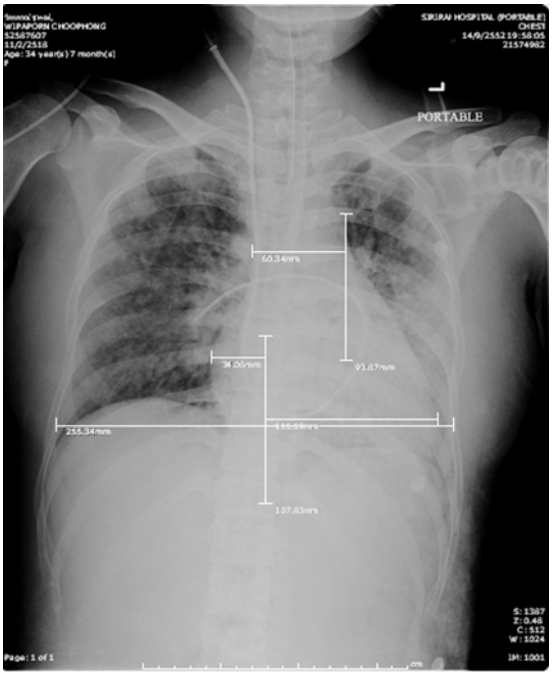

Fig. 1 Demonstrates the measurement of vascular pedicle width (VPW) and cardiothoracic ratio (CTR). VPW is the distance from an imaginary perpendicular line from the junction of superior vena cava shadow (assuming from the pulmonary artery catheter or other central venous catheter in the superior vena cava) and the right main bronchus to an imaginary perpendicular line from the origin of subclavian artery to the arch of aorta. The maximum cardiac shadow measured from the distance from the imaginary perpendicular line along the spinous process to the most distant of left and right cardiac borders. The CTR is the ratio of the maximum cardiac shadow width and the thoracic cage.

Hemodynamic parameters measurement

The hemodynamic parameters, including the CVP and the PAOP, were measured when the patient was in the supine position. The fluid filling system was calibrated to zero at the mid chest level and the pressure value at the end of expiration was recorded.

Ethical consideration

This study was reviewed and approved by the Siriraj hospital's ethical committee, using the Declaration of Helsinki.

Statistics

The patients' baseline characteristic, hemodynamic parameters and CXR parameters were reported as mean ± standard deviation (SD) and percentage. The comparison between the patient groups was performed by using the Pearson's Chi square test or Fisher's exact test for categorical data and by unpaired t-test for continuous variables. The correlations between the PAOP and CXR parameters were determined by the logistic regression model. The predictive cutoff point of CXR parameters to predict the PAOP > 18 mmHg was assessed by the receiver operating characteristic (ROC) curve. The accuracy of each cutoff point was shown as the sensitivity, the specificity, the positive predictive value and the negative predictive value. The p-value less than 0.05 was considered as a statistical significant. The SPSS version 17 was used for statistical analysis.

Results

Thirty four patients were included in this study. Among these, thirteen patients (38.2%) had PAOP ≥ 18 mmHg (elevated PAOP group). The patients' baseline characteristics, hemodynamic parameters and CXR parameters were shown in Table 1. The patients with elevated PAOP were older, taller and heavier than the other. The preliminary diagnosis of the patients was not difference between the two groups. The leading diagnosis was congestive heart failure, followed by severe sepsis/septic shock, acute respiratory distress syndrome (ARDS) and respiratory tract infection. The proportion of patients with high jugular venous pressure (JVP > 3 cmH_2O) and the mean CVP level were not difference in both groups.

CXR parameters and the PAOP

As shown in Table 1, the VPW and CTR, were significantly higher in the elevated PAOP group, however, neither the ratio of VPW over the chest wall distance (VPW/CW) nor the VPW over CTR is different between the groups. The peribronchial cuffing presented in higher proportion of patients with higher PAOP. To evaluate the correlation of the VPW and the CTR with the PAOP, the scatter plot was performed.

Table 1. Patients' characteristics according to the PAOP level.

Clinical variables	PAOP ≥ 18 mmHg (n = 13)	PAOP < 18 mmHg (n = 21)	p
Sex (% male)	76.9	42.9	0.25
Age (year)	69.8 ± 8.8	59.2 ± 15.4	0.02*
Height (cm)	163.2 ± 5.3	157.0 ± 10.4	0.03*
Body weight (kg)	67.4 ± 12.9	57.1 ± 7.8	0.007*
BMI (kg/m^2)	25.2 ± 4.5	23.2 ± 3.2	0.14
Suspected diagnosis (%)			0.83
Congestive heart failure	46.2	33.3	
Bacteremia	30.8	28.6	
ARDS	15.4	28.6	
Pneumonia	7.7	4.8	
Others	0	4.8	
Hemodynamic parameters			
JVP > 3 cm (%)	38.5	38.1	0.98
CVP (mmHg)	15.8 ± 5.6	13.2 ± 6.5	0.26
PAOP (mmHg)	21.0 ± 2.5	13.1 ± 3.4	<0.001*
CXR parameters			
VPW (mm)	75.6 ± 6.9	63.9 ± 6.8	<0.001*
CTR	0.63 ± 0.06	0.58 ± 0.07	0.03*
VPW/CW	0.43 ± 0.07	0.42 ± 0.06	0.68
VPW/CTR	121.5 ± 21.1	112.0 ± 18.6	0.18
Peribronchial cuffing (%)	76.9	33.3	0.03*
Septal line (%)	46.2	33.3	0.46
Air bronchogram (%)	30.8	33.3	0.88

*p-value < 0.05 (significant)

The figure 2a shows a significant positive correlation between the VPW and the PAOP level with r = 0.683, P <0.001, while figure 2b shows a weakly positive correlation between the CTR and the PAOP level with r = 0.267, P=0.03.

Cut off point for predicting PAOP ≥18 mmHg

The receiver operating characteristic (ROC) curve was preformed to evaluate the accuracy of VPW and CTR for predicting the elevation of PAOP. The area under the curve (AUC) of VPW for predicting elevation of PAOP was 0.853 with P < 0.001 and the AUC of CTR for predicting elevation of PAOP was 0.727 with P = 0.03. According to the ROC curve the VPW ≥ 68 mm can be used as the cutoff point to predict PAOP ≥ 18 mmHg with the sensitivity of 92.3% and the specificity of 85.7%. The cutoff point of CTR to predict PAOP ≥ 18 mmHg was CTR ≥ 0.58 (sensitivity = 61.9% and specificity = 76.9%). Table 2 shows the sensitivity, the specificity, the positive predictive value, the negative predictive value and the accuracy for the using of VPW, CTR and peribronchial cuffing to predict elevation of PAOP.

Discussion

The CXR parameters, especially VPW and CTR had been reported as a good predictor for evaluate volume status of the critically ill patients[15-18]. Most of studies reported that the VPW > 70 mm and the CTR > 0.55 were the cutoff point for prediction of the elevated PAOP[15]. Considering the difference in the patients' body sizes which varies among the different ethnic groups, this study enable us to identify the cut off point for Thai patients whose body sizes are smaller than the Caucasian. The results from the study support our hypothesis that the VPW and CTR correlated well with the PAOP and the VPW ≥ 68 mm as well as the CTR ≥ 0.58 are the cutoff point to predict elevation of PAOP.

There are certain limitations of this study. First, our study was not designed to evaluate the inter-observer and the intra-observer variations. The accuracy of this test may vary, depending on the experience of the physician. Second, the body size of

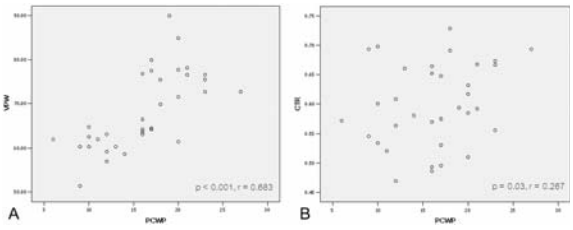

Fig. 2 This scatter plot show significant linear correlation between PAOP in X-axis and VPW in Y-axis (A), and between PAOP in X-axis and CTR in Y-axis (B)

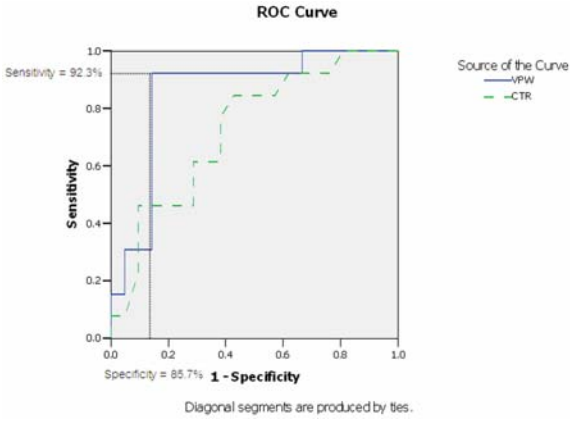

Fig. 3 The Receiver operating characteristic (ROC) curve performed to access the accuracy of the VPW and CTO measuring from portable CXR in predicting the intravascular volume status among Thai medical critically ill patients. The areas under the curve (AUC) of VPW and CTR were 0.853 with p < 0.001 and the AUC of CTR for predicting* elevation of PAOP was 0.727 with p = 0.03.

Table 2. CXR parameters (VPW ≥ 68 mm, CTR ≥ 0.58 and positive of peribronchial cuffing) to predict elevation of PAOP ≥ 18 mmHg

CXR parameters	Sens	Spec	PPV	NPV	Acc	Odds ratio (95%CI)	p
VPW > 68 mm	92.3%	85.7%	80%	94.7%	88.2%	16.4 (4.7-29.7)	<0.001*
CTR > 0.58	61.9%	76.9%	55.5%	81.3%	67.6%	4.85 (1.1-2.58)	0.03*
Peribronchial cuffing	76.9%	66.7%	58.8%	82.4%	70.6%	4.85 (1.1-25.8)	0.03*

Sens = sensitivity, Spec = specificity, PPV = positive predictive value, NPV = negative predictive value, Acc = accuracy
*p-value < 0.05 (significant)

the patients with high PAOP in this study was significantly larger than the lower PAOP group. The difference of the body size might effect to the cutoff point of CXR parameter, especially the VPW more than the CTR. It may be possible that the actual cutoff point of VPW among Thai patients which is able to predict high PAOP should be lower than 68 mm. For the CTR, the cutoff point of this parameter would be the same in either larger or smaller body. This is because this parameter has been corrected with body size by dividing the cardiac shadow by the chest wall distance. Thirdly, the CXR were not performed at the same time with the hemodynamic parameters measurement. Although, we try to limit the time gap between the hemodynamic evaluations and the CXR less than one hour, there still a chance for difference in intravascular volume status from the continuing treatment, such as rapid rate of fluid administration to develop. Fourthly this is a prospective study so we can control the patient position and the x-ray resource-to-chest wall distance. The application of the CXR parameters from this study should strictly control all of these aspects.

In addition to the variation of the patient's body size and the distance of the X-ray resource and the patient's chest wall, the experience of the physician can also affect the accuracy of the prediction of the PAOP by CXR parameters. There may be a need for the inclusion of a larger patients as well as a design for inter-observer and intra-observer evaluation before generally using this test in routine practice.

Conclusion

The increasing of the VPW, the CTR and the presence of the peribronchial cuffing can be used to predict the elevation of PAOP among the critically ill patient with considerable accuracy. The careful CXR interpretation is very helpful for intravascular volume evaluation, especially for the patient who has contraindication for invasive hemodynamic monitoring and for the patient admitted to a hospital where PAC and other noninvasive equipment was not available.

Potential conflicts of interest

None.

References

1. Bigatello LM, George E. Hemodynamic monitoring. Minerva Anestesiol 2002; 68: 219-25.
2. Badgett RG, Lucey CR, Mulrow CD. Can the clinical examination diagnose left-sided heart failure in adults? JAMA 1997; 277: 1712-9.
3. Harvey S, Young D, Brampton W, Cooper AB, Doig G, Sibbald W, et al. Pulmonary artery catheters for adult patients in intensive care. Cochrane Database Syst Rev 2006; 3: CD003408.
4. Richard C, Warszawski J, Anguel N, Deye N, Combes A, Barnoud D, et al. Early use of the pulmonary artery catheter and outcomes in patients with shock and acute respiratory distress syndrome: a randomized controlled trial. JAMA 2003; 290: 2713-20.
5. Combes A, Arnoult F, Trouillet JL. Tissue Doppler imaging estimation of pulmonary artery occlusion pressure in ICU patients. Intensive Care Med 2004; 30: 75-81.
6. Voga G. Pulmonary artery occlusion pressure estimation by transesophageal echocardiography: is simpler better? Crit Care 2008; 12: 127.
7. Harvey S, Harrison DA, Singer M, Ashcroft J, Jones CM, Elbourne D, et al. Assessment of the clinical effectiveness of pulmonary artery catheters in management of patients in intensive care (PAC-Man): a randomised controlled trial. Lancet 2005; 366: 472-7.
8. Shah MR, Hasselblad V, Stevenson LW, Binanay C, O'Connor CM, Sopko G, et al. Impact of the pulmonary artery catheter in critically ill patients: meta-analysis of randomized clinical trials. JAMA 2005; 294: 1664-70.
9. Harvey S, Stevens K, Harrison D, Young D, Brampton W, McCabe C, et al. An evaluation of the clinical and cost-effectiveness of pulmonary artery catheters in patient management in intensive care: a systematic review and a randomised controlled trial. Health Technol Assess 2006; 10: iii-iv, ix-xi, 1-133.
10. Brandstetter RD, Grant GR, Estilo M, Rahim F, Singh K, Gitler B. Swan-Ganz catheter: misconceptions, pitfalls, and incomplete user knowledge—an identified trilogy in need of correction. Heart Lung 1998; 27: 218-22.
11. Binanay C, Califf RM, Hasselblad V, O'Connor CM, Shah MR, Sopko G, et al. Evaluation study of congestive heart failure and pulmonary artery catheterization effectiveness: the ESCAPE trial. JAMA 2005; 294: 1625-33.
12. Rihal CS, Davis KB, Kennedy JW, Gersh BJ. The utility of clinical, electrocardiographic, and roentgenographic variables in the prediction of left ventricular function. Am J Cardiol 1995; 75: 220-3.
13. Aberle DR, Wiener-Kronish JP, Webb WR, Matthay MA. Hydrostatic versus increased per-

meability pulmonary edema: diagnosis based on radiographic criteria in critically ill patients. Radiology 1988; 168: 73-9.
14. Duarte AG. Radiographic assessment of intravascular volume. Chest 2002; 122: 1879-81.
15. Ely EW, Haponik EF. Using the chest radiograph to determine intravascular volume status: the role of vascular pedicle width. Chest 2002; 121: 942-50.
16. Thomason JW, Ely EW, Chiles C, Ferretti G, Freimanis RI, Haponik EF. Appraising pulmonary edema using supine chest roentgenograms in ventilated patients. Am J Respir Crit Care Med 1998; 157: 1600-8.
17. Miller RR, Ely EW. Radiographic measures of intravascular volume status: the role of vascular pedicle width. Curr Opin Crit Care 2006; 12: 255-62.
18. Martin GS, Ely EW, Carroll FE, Bernard GR. Findings on the portable chest radiograph correlate with fluid balance in critically ill patients. Chest 2002; 122: 2087-95.

ความสัมพันธ์ระหว่างปริมาณสารน้ำในหลอดเลือด และ vascular pedicle width ในผู้ป่วยวิกฤตคนไทย

ศานิต วิชานศวกุล, วรการ วิไลชนม์, สุรัตน์ ทองอยู่, ไชยรัตน์ เพิ่มพิกุล, สุวิมล วงศ์ลักษณะพิมล, กัณฑ์ธิมา แดงนิ่ม, จิรพงศ์ สุวรรณบุญฤทธิ์

วัตถุประสงค์: *เพื่อหาความสัมพันธ์ระหว่างค่าความกว้างของหลอดเลือดในช่องทรวงอก หรือ vascular pedicle width (VPW) จากการวัดจากภาพถ่ายรังสีทรวงอกชนิด portable และปริมาณสารน้ำในหลอดเลือดของผู้ป่วยวิกฤตคนไทย*

วัสดุและวิธีการ: *การศึกษานี้เป็นการศึกษาโดยวิธีการเก็บข้อมูลแบบไปข้างหน้า โดยเก็บข้อมูลพื้นฐานของผู้ป่วยและข้อมูลเกี่ยวกับระบบไหลเวียนโลหิต ซึ่งได้จากการใส่สายวัดความดันในหลอดเลือดแดงปอด (pulmonary artery catheter, PAC) และจากภาพถ่ายรังสีทรวงอกในผู้ป่วยวิกฤตคนไทยซึ่งรับไว้ดูแลในหอผู้ป่วยวิกฤตอายุรศาสตร์ โรงพยาบาลศิริราช มหาวิทยาลัยมหิดล ตั้งแต่เดือนมิถุนายน 2552 ถึงเดือนมกราคม 2553*

ผลการศึกษา: *จากการเก็บข้อมูลผู้ป่วยวิกฤตจำนวน 34 คน มีผู้ป่วยที่มีความดันในหลอดเลือดแดงปอดสูง (pulmonary artery occlusive pressure, PAOP) $\geq$ 18 มิลลิเมตรปรอท (มม.ปรอท) จำนวน 13 คน (38.2%) เมื่อเปรียบเทียบกับกลุ่มที่มีความดันหลอดเลือดแดงในปอดปกติ พบว่ากลุ่มนี้มีอายุมากกว่า (69.8$\pm$8.8 ปี เปรียบเทียบกับ 59.2$\pm$15.4 ปี, p =0.02), ส่วนสูงมากกว่า (163.2$\pm$5.3 เซนติเมตร เปรียบเทียบกับ157.0$\pm$10.4 เซนติเมตร, p =0.03) และมีน้ำหนักตัวมากกว่า (67.4$\pm$12.9 กิโลกรัม เปรียบเทียบกับ 57.1$\pm$7.8 กิโลกรัม, p =0.007) และพบมีความสัมพันธ์กันอย่างมีนัยสำคัญทางสถิติระหว่างค่าPAOP และค่า VPW (p <0.001, r =0.68) หรือ cardiothoracic ratio (CTR) (p =0.04, r =0.23) สำหรับการหาความสัมพันธ์โดยวิธี receiver operating characteristic (ROC) curve นั้น พบว่าค่า VPW >68 มิลลิเมตร เป็นค่าที่ดีที่สุดในการทำนายค่า PAOP $\geq$18 มม.ปรอท ที่พื้นที่ใต้กราฟ (area under the curve, AUC) เท่ากับ 0.853, p <0.001 มีsensitivity ร้อยละ 92.3 และspecificity ร้อยละ 85.7 และCTR >0.58 สามารถใช้ทำนายค่า PAOP $\geq$18 มม.ปรอทได้ โดยมีค่า sensitivity ร้อยละ 85.7 และspecificity ร้อยละ76.9 (AUC =0.727,p =0.03) และจากภาพถ่ายรังสีทรวงอกยังพบว่าในกลุ่มที่มี PAOPสูง พบมี peribronchial cuffing มากกว่าในกลุ่มที่มี PAOP ต่ำกว่า (ร้อยละ 76.9 เปรียบเทียบกับร้อยละ 33.3, p=0.03)*

สรุป: *ในผู้ป่วยวิกฤตคนไทยนั้นสามารถใช้ค่า VPW >68 มิลลิเมตรปรอท, CTR >0.58 และการพบมี peribronchial cuffing จากภาพถ่ายรังสีทรวงอกร่วมกันในการใช้ทำนายการมีค่า PAOP $\geq$18 มม.ปรอทได้ดี โดยการใช้ข้อมูลจากภาพถ่ายรังสีทรวงอกดังกล่าว จะช่วยลดการใส่สายวัดความดันหลอดเลือดแดงปอดที่เกินความจำเป็น อันจะนำมาซึ่งการลดลงของการเกิดภาวะแทรกซ้อนจากการใส่สายวัดความดันหลอดเลือดแดงปอดได้*