

# Survey on the knowledge of transpulmonary thermodilution as obtained with the PiCCO haemodynamic monitoring device

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## Introduction and background

Optimal treatment of the critically ill patient demands adequate, precise and continuous monitoring of clinical parameters. Recent studies show that application of hemodynamic monitoring can improve outcome. Pulse Contour Cardiac Output monitoring with transpulmonary thermodilution (TPTD) obtained with the PiCCO system (Pulsion Medical Systems, Munich, Germany) provides information on fluid status, fluid responsiveness, cardiac output (CO), contractility of the myocardium and severity of the pulmonary edema [1]. The PiCCO is a less invasive hemodynamic monitoring device than the pulmonary artery catheter (PAC), and is increasingly being used as a haemodynamic monitoring tool to guide management in critically ill patients. No research has previously been performed on staff knowledge of basic principles and practical implementation of transpulmonary thermodilution (TPTD) measurements at the bedside. Methods

We set up a descriptive trial in which medical and paramedical ICU personnel was asked to participate in a written or online survey. The survey consisted of 25 questions based upon the information found in the manual of the PiCCO system. During a 6 month period in 2009 we performed a survey among nursing and medical staff from different ICUs in Belgium and the Netherlands on the knowledge on the basic principles and practical use of the PiCCO haemodynamic monitoring system. They were asked to complete an online questionnaire with 1 open and 24 multiple choice questions. An English translation of the questionnaire, originally in Dutch, with correct answers is available as an attachment.

## Results

In total, 252 persons participated in the survey: 196 nurses (78%) and 56 medical doctors (22%) of which 17 residents in training. About 78.6% of the respondents knew that a PiCCO CO measurement is performed intermittently by TPTD and on a continuous basis by arterial pulse contour analysis. About 43% were convinced that a PiCCO measurement is an invasive procedure, while in fact it is considered minimally invasive. The basic knowledge on CO calibration appeared to be insufficient: 59 respondents (23.3%) did not know that the temperature of the bolus injectate (Ti) should be below 8°C. Regarding the volume of the injectate (Vi), only 55 (21.8%) correctly stated that it should be adjusted according to body weight (0.2 ml/kg), with a maximum of 20 ml. 162 (64.3%) Participants knew how fast the cold injectate needs to be administered (<7 seconds or 2.5 ml/sec) and 153 (60.7%) faulty believed that a patient needs to be in supine position for the measurement. About 138 Persons (54.8%) stated correctly that the PiCCO needs to be calibrated only once every nursing shift, but only 91 (36.1%) knew that a rapid flush test should be performed before each measurement. A further 65.5% Of the participants recognized the curve of a correct rapid flush test, while 36.9 % did not know why to perform the rapid flush test. About 41.7% of the participants knew that stroke volume variation (SVV) and pulse pressure variation (PPV) are unreliable if the patient is not in sinus rhythm, whereas 26.6% didn't recognize the atrial fibrillation as an underlying rhythm stated in question 24. A total of 178 (70.6%) stated correctly that the placement of the venous and arterial femoral catheters is important for the interpretation of the obtained values. Table 1 lists the correct answers on the different questions. The overall score with correct answers was  $58.3 \pm 15.1\%$  (Fig. 1). The doctors performed better than nurses (62.7% vs 57.0%,  $p=0.012$ ), no difference was found

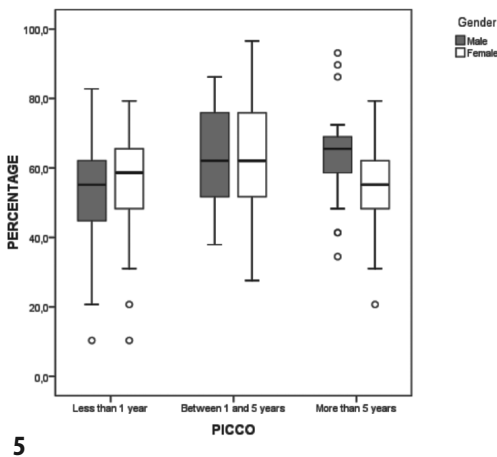
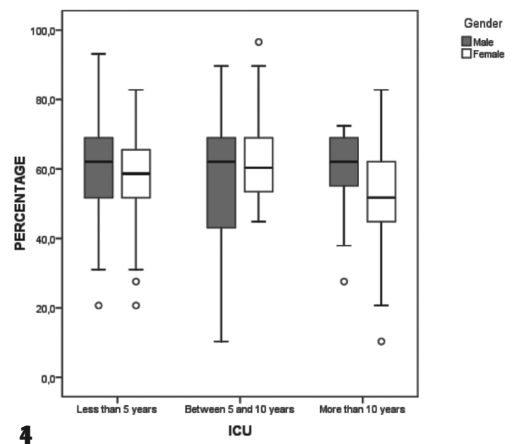
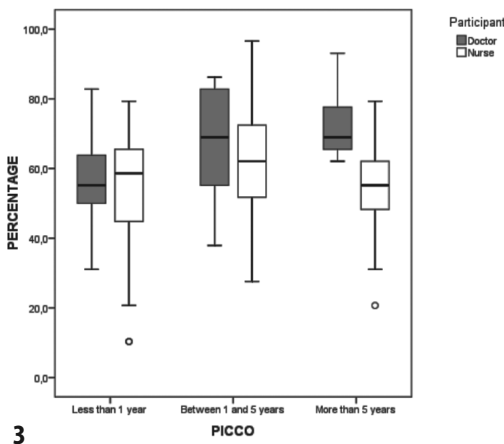
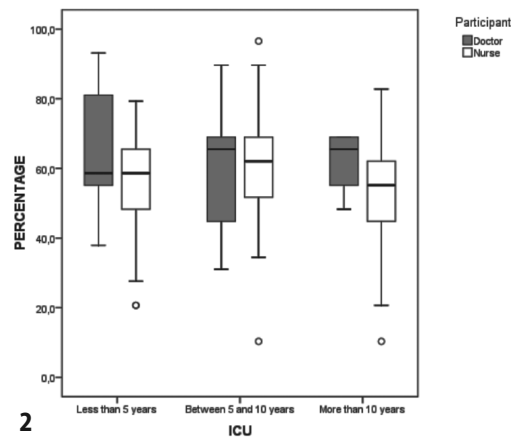
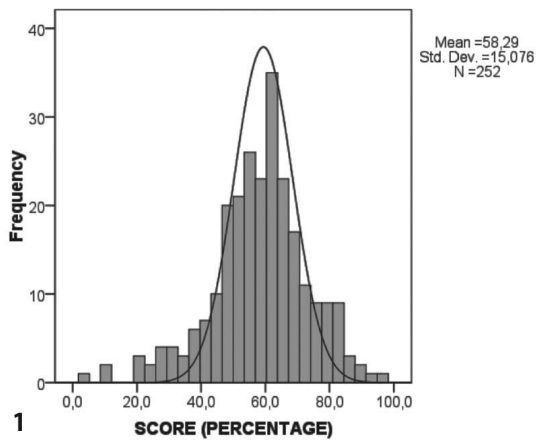


Fig. 1. Histogram displaying the frequency of average scores (in percentage) on the knowledge questions.  
 Fig. 2. Boxplots showing median scores (as percentage) for doctors as compared to nurses according to the number of years of ICU experience. The *p*-values were NS except for the group with more than 10 years ICU experience ( $p=0.05$ )  
 Fig. 3. Boxplots showing median scores (as percentage) for doctors as compared to nurses according to the number of years of PiCCO experience. The *p*-values were NS except for the group with more than 5 years PiCCO experience ( $p<0.0001$ )  
 Fig. 4. Boxplots showing median scores (as percentage) for men as compared to women according to the number of years of ICU experience. All the *p*-values were NS.  
 Fig. 5. Boxplots showing median scores (as percentage) for man as compared to woman according to the number of years of PiCCO experience. The *p*-values were NS except for the group with more than 5 years PiCCO experience ( $p=0.012$ )

between male and female respondents (59.4% vs 57.6%) or between Belgian and Dutch respondents (57.3% vs 59.5%). About 190 out of 252 (75.4%) scored at least 50% whereas only 45 respondents (17.9%) obtained a score of 70% or more. The amount of years of ICU experience is inversely related with the knowledge on PiCCO. Persons who have more than 10 years of ICU experience scored less (54.5%) on the knowledge questions than personnel with 5 to 10 years (60.5%) and those with less than 5 years ICU experience (59.8%) respectively, with no significant difference between doctors and nurses except for

those with more than 10 years experience (Fig. 2). Doctors (72.4%) performed better than nurses (54.5%) in the group of personnel with more than 5 years of PiCCO experience (Fig. 3). Figure 4 shows the different scores in men compared to women with regard to years of ICU experience, while Figure 5 show the same results in relation to years of PiCCO experience. In the group of respondents having more than 5 years of PiCCO experience, men (64.0%) showed significant better results than women (54.3%). There was no significant difference in the results related to gender in the group with less than 5 years of PiCCO experience.

Having 5 years of PiCCO experience was present in 15.8% of the total number of participants and this was related to passing the test (obtaining  $\geq 50\%$ ) ( $p=0.07$ ) or obtaining a test result of  $\geq 70\%$  ( $p=0.05$ ). There were no other parameters significantly predictive for obtaining a result above 50% or above 70% like gender, doctor versus nurse, Belgian versus Dutch residency or years of ICU experience.

## Discussion

PiCCO has gained its place in the haemodynamic monitoring field, but as with any new technique, its virtue is only fully appreciated with correct use and interpretation. From our survey, we can conclude that the knowledge on the use and interpretation of the PiCCO, although being used regularly, was suboptimal among the ICU personnel. As with all new

technologies, its usefulness relies on correct understanding of the principles, a flawless measurement technique and a correct interpretation of the obtained values in different scenarios. From our survey among ICU personnel, it appears that knowledge on transpulmonary thermodilution appears to be suboptimal and high quality education of ICU staff is necessary to exploit the information that can be obtained. Specific thermodilution curves can point towards specific diagnoses and an interpretation of acquired parameters in specific conditions is suggested.

## References

1. Malbrain M, De Potter T, Deeren D. Cost-effectiveness of minimally invasive hemodynamic monitoring. In: Yearbook of Intensive Care and emergency Medicine. Vincent JL (ed), Springer-Verlag, 2005, pp. 603--631

## Appendix: Survey on the knowledge of transpulmonary thermodilution in the ICU.

Questionnaire about the use of PiCCO. More answers per question are possible

1. What does PiCCO mean? (open question)
2. What principles are used with PiCCO measurements?
  - a. intermittent and continuous CO measurement by arterial pulse contour analysis
  - b. intermittent by thermodilution and continuous by arterial pulse contour analysis
  - c. intermittent and continuous measurements by thermodilution
  - d. I have no idea
3. What does PiCCO measure besides cardiac output?
  - a. preload
  - b. contractibility
  - c. extravascular lung water
  - d. filling status
  - e. wedge pressure
  - a. afterload
  - g. all answers are correct
  - h. all answers are incorrect
4. Hemodynamic monitoring with the PiCCO is:
  - a. invasive
  - b. minimal invasive
  - c. not invasive
  - d. I have no idea
5. In which patients is the use of PiCCO appropriate?
  - a. burned patients
  - b. patients with septic shock
  - c. patients undergoing major surgery that need cardiovascular monitoring
  - d. patients with unknown filling status
  - e. patients with kidney failure
  - f. patients with respiratory failure

- g. all answers above
- h. I have no idea
- I. other: [ ]

6. What do we need, to perform a PiCCO measurement?
  - a. central venous catheter, PiCCO catheter, and a PiCCO kit
  - b. arterial catheter, PiCCO catheter, and a PiCCO kit
  - c. only a PiCCO kit
  - d. Swan-Ganz catheter
  - e. I have no idea
7. What is the correct injectate temperature ( $T_i$ )?
  - a.  $<5^\circ\text{C}$
  - b.  $<8^\circ\text{C}$
  - c.  $<12^\circ\text{C}$
  - d. ambient temperature
  - e. I have no idea
8. Is the volume of the injectate ( $V_i$ ) dependent on the body weight?
  - a. yes
  - b. no
  - c. yes, with a maximum of 100 kg
  - d. I have no idea
9. Is it important to enter information like weight and height of the patient?
  - a. yes, jto present correctly the indexed values
  - b. no, weight and height are not important
  - c. only length is important because the PiCCO calculates the predicted body weight (PBW)
  - d. I have no idea
10. Should the patient be supine during a TPTD measurement?
  - a. yes
  - b. no, it is of no importance
  - c. head of bed should be elevated at  $30^\circ$ -  $40^\circ$
  - d. I have no idea

11. How many measurements must at least be done to obtain a correct value?
- 2 measurements
  - 3 measurements
  - 4 measurements
  - I have no idea

12. Which deviation from the mean CO is allowed for a thermodilution CO measurement?
- 10%
  - 15%
  - 20%
  - 25%
  - more than 25%

13. What values should be noted for volumes and extravascular lung water?
- the indexed value
  - the absolute value
  - both are possible
  - I have no idea

14. How many times does the PiCCO arterial curve need to be zeroed / calibrated?
- at least once a day
  - before each measurement
  - only when starting up the PiCCO
  - once per shift
  - once per week
  - once per month
  - I have no idea

15. Why do we perform a rapid flush test?
- to check if the curve is damped
  - to see if there is a leak
  - to check if the pressure bag is sufficiently inflated
  - to measure the CO
  - I have no idea

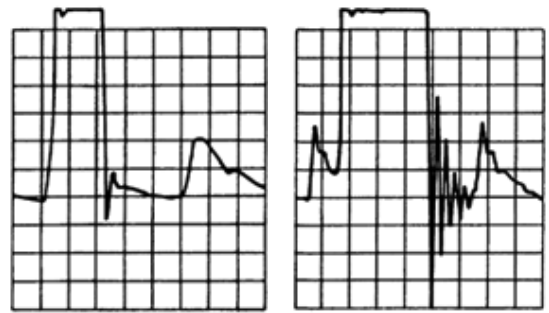
16. When do we perform a rapid flush test?
- once a day
  - once per shift
  - before each TPTD measurement
  - I have no idea

17. Which of these rapid flush tests are correct or explain the pressure signal?

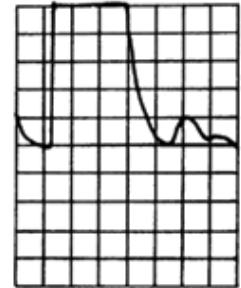
- 17A. Curve 1
- damped signal
  - normal signal
  - augmented signal

- 17B. Curve 2
- damped signal
  - normal signal
  - augmented signal

- 17C. Curve 3
- damped signal
  - normal signal



A ↑, B ↗, C →



6. augmented signal

18. Question A: Is the placement of the catheters important for the interpretation of the

- obtained values?
- yes
- no
- I have no idea

18. Question B: Which of the following is the ideal catheter position?

- right jugular vein/left or right femoral artery
- left femoral vein/right femoral artery
- left subclavian vein/left or right femoral artery
- I have no idea

18. The injectate should be injected:

- in less than 7 seconds
- in less than 10 seconds
- in less than 12 seconds
- depending of the amount of injected volume, always 5cc/2 sec

19. What to do if the delta T° is less than 0.2°C?

- increase the cooling of the injectate
- increase the speed of injection
- increase the volume of the injectate
- I have no idea

20. What happens if the injectate volume is less than the amount expected by the PiCCO?

- false increase of the CO
- false decrease of the EVLWi
- false increase of the CI
- false decrease of the GEDVi
- I have no idea

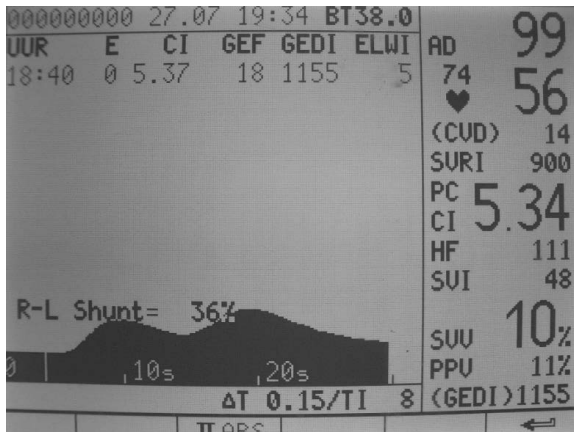
21. Should the CVP be entered in the PiCCO?

- no, it is calculated by PiCCO
- yes, to calculate the cardiac output

- c. yes, to calculate the systemic vascular resistance
- d. I have no idea

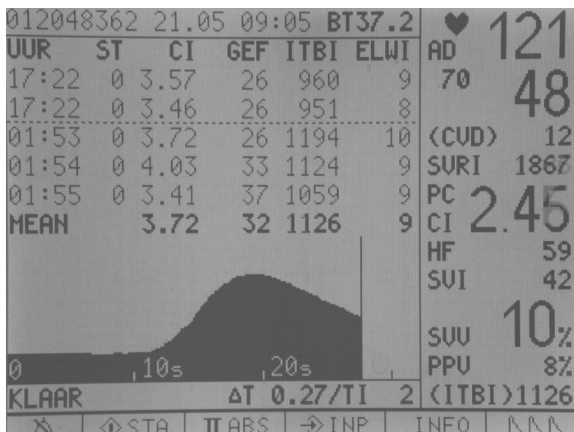
22. Look at the following thermodilution curves and state if performed correctly

23A. Curve 1



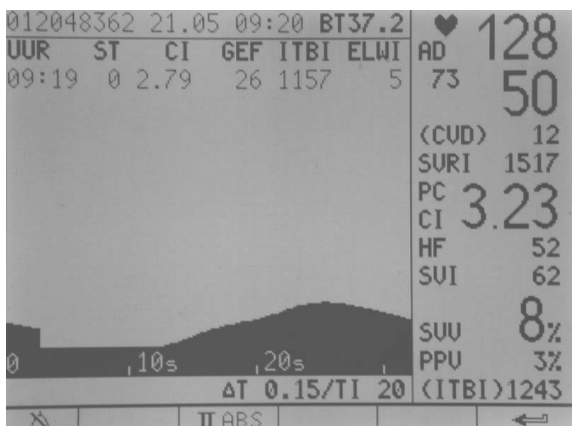
- a. correct
- b. incorrect
- c. I have no idea

23B. Curve 2



- a. correct
- b. incorrect
- c. I have no idea

23C. Curve 3

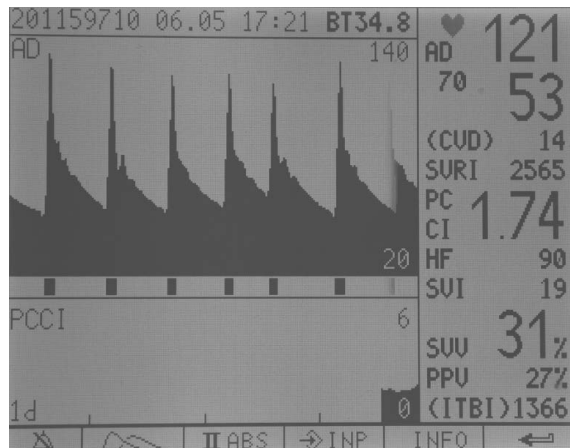


- 1. correct
- 2. incorrect
- 3. I have no idea

23. Determine the underlying rhythm

- a. regular sinus
- b. atrial fibrillation
- c. irregular
- d. I have no idea

24. Which PiCCO measurements are not reliable if the patient is not in sinus rhythm?



- a. all measurements are reliable
- b. all measurements are unreliable
- c. the pulse contour analysis is reliable
- d. SVV and PPV are unreliable
- e. the thermodilution measurements (GEDVi and EVLWi) are reliable
- f. I have no idea

25. To finish this survey some questions about you :

- a. What is your gender?  man,  woman
- b. Are you a doctor or a nurse?  doctor,  trainee,  nurse
- c. In which country do you work?  Belgium  The Netherlands  Other
- d. In which city do you work?
- e. On which ICU do you work?
- f.  Medical ICU
- g.  Surgical ICU
- h.  Mixed ICU
- i.  CCU
- j.  Burn Unit
- k.  Other
- l. How many years do you work in the ICU? \*
- m. What is your experience (in years) with PiCCO? \*