CASE REPORT

The “cross-talk phenomenon” in transpulmonary thermodilution is blood-flow dependent

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Abstract - Transpulmonary thermodilution (TPTD) using the injection of ice-cold saline is a reliable technique for measuring cardiac output in adults and children. We describe two cases in which these measurements were erroneously influenced by diffusion of the temperature indicator. If the thermistor-tipped arterial catheter is in close proximity to the central venous catheter, the injection of an ice-cold indicator might lead to an early temperature drop in the arterial catheter thus producing a biphasic dilution curve. This is called the “cross-talk phenomenon”. In the first case, concerning a child undergoing congenital cardiac surgery, we show that this phenomenon is dependent on blood flow. In the second case we demonstrate an animal experiment in which the cross-talk phenomenon occurred during a very low flow state. However in this case the venous catheter was positioned in the inferior caval vein and not in close proximity to the arterial catheter. The cross-talk phenomenon can also occur when the arterial catheter is not in close position to the central venous catheter. We conclude that when using TPTD measurements with arterial and venous catheters both positioned in the lower body, the cross-talk phenomenon may occur. Therefore the thermodilution curve should always be closely monitored for a biphasic shape, especially when the cardiac output is low.

Keywords - Cardiac output, transpulmonary thermodilution, cross-talk phenomenon, haemodynamic monitoring

Introduction
Transpulmonary thermodilution (TPTD) is a reliable technique for measuring cardiac output in adults and children [1 – 4]. Using a thermistor-tipped arterial catheter and a monitoring device (PiCCO, Pulsion Medical Systems, Munich, Germany) a temperature - dilution curve can be registered when an ice-cold solution is injected into a central venous catheter. Cardiac output is calculated according to the Stewart Hamilton equation [5]. By using the TPTD technique it is also possible to detect a right-to-left intra-cardiac shunt because, in these instances, the TPTD curve becomes biphasic [6]. However, a biphasic curve can also occur if the injection port of the central venous catheter and the thermistor-tipped arterial line are positioned closely together. This is described as the “cross-talk phenomenon” [7]. The cross-talk phenomenon occurs when the temperature indicator reaches the arterial thermistor directly after injection because of diffusion through tissues. After the indicator has travelled in the bloodstream through the heart and great vessels it reaches the thermistor for the second time causing a biphasic thermodilution curve. Based upon two observations, we conclude that the cross-talk phenomenon is dependent on blood flow (e.g. cardiac output).

Case 1
A 10-month-old child, weighing 6.5 kg and 66 cm in length, underwent a valvulotomy for congenital pulmonary valve stenosis. The preoperative diagnostic work up revealed no intra-or extra-cardiac shunts nor was there any significant valvular regurgitation present. After induction of general anaesthesia and the initiation of mechanical ventilation, a 7-cm-long 3-Fr arterial line was inserted into the right femoral artery. An 8-cm-long triple lumen 5.5-Fr femoral central venous line was inserted on the same side. A fast bolus injection of three millilitres of ice-cold saline was used for TPTD measurement. The PiCCOplus device was used together with a laptop computer with the special PICCOwin software (Pulsion, Munich, Germany). This equipment allows the user to store not only all PICCO measurements but also the thermodilution curves for analysis afterwards. The first TPTD measurement showed a huge biphasic shape (Figure 1, left curve). It was noted that the time interval between injection and first detection of the indicator was very short. It took 3.3 seconds to reach the first lowest blood temperature whereas it took 10 seconds to reach the second lowest value. A reliable calculation of cardiac output (CO) was impossible. The heart rate (HR) was 125 bpm and the mean arterial pressure (MAP) was 56 mmHg. Clinically, cardiac output (CO) was low as the child was peripherally cold and mottled. Also the child was hypothermic after induction of anaesthesia, with a blood temperature of 35.7 C. No other clinical signs of serious circulatory failure were recorded. Reconstruction of the thermodilution curve using only the secondary part of this curve (omitting the grey area in the left curve of Figure 1) resulted in an estimated cardiac index of 2.3 l×min⁻¹×m⁻². The haemodynamic status improved after administration of fluids. Post-operatively another thermodilution measurement, using the same arterial and venous catheter, was performed. This time a completely different curve (Figure 1, right curve) was produced also using 3 ml of ice-cold saline. Now the

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cross-talk phenomenon could not be observed. Heart rate at that time was 159 bpm, MAP was 70 mmHg, blood temperature was 37.6°C, cardiac index was 4.2 l×min⁻¹×m⁻² and the child was clinically in a good haemodynamic state with warm extremities. The interval time between injection and lowest blood temperature in this series of measurements was 7.6 sec.

**Case 2**

During an animal experiment investigating haemodynamic stabilization after experimental surgery, we used the TPTD technology to measure cardiac output. A 7 cm 3 French arterial Pulsiocath catheter in the femoral artery was used in conjunction with a single-lumen venous catheter. The venous catheter was surgically advanced through the femoral vein. Using the same PICCOplus device and storage facility described in Case 1, we measured cardiac output in a rhesus monkey of 12 kg weight and 100 cm height using an ice-cold infusion of 3 ml normal saline. The animal was in a clinical state of profound haemodynamic shock. At the time of the first TPTD measurement the heart rate was 110 bpm and blood pressure 42/29/24 mmHg (SAP/MAP and DAP respectively). An abnormal thermodilution curve was recorded (Figure 2 left curve). Again the time interval between injection and first reaction of blood temperature was short (5.6 sec). A radiographic study was performed to verify the position of the venous catheter as it was suspected that it was positioned close to the thermistor-tipped arterial catheter. The tip however was located in the inferior caval vein just cranial of the bifurcation. The arterial catheter was positioned in the iliac artery, not adjacent to the venous catheter. Subsequently the venous catheter was advanced under radiographic guidance until it reached the level of the right atrium. Within 20 minutes a second TPTD measurement was performed. This time a normal TPTD curve was observed (Figure 2 right curve). Blood pressure and heart rate were similar and cardiac index was 0.74 l×min⁻¹×m⁻². The time interval between injection and lowest blood temperature was prolonged to 14.4 seconds as might be expected with a very low cardiac output.

**Discussion**

In adjunct to the experiences of Michard and colleagues, we propose that the venous injection of ice-cold saline close to the thermistor-tipped arterial line produces a local change in temperature, which influences the reading of the arterial thermistor [7]. This was demonstrated in Case 1 (Figure 1 left curve). Not only the thermodilution curve was biphasic but also the interval between injection and detection of a temperature change was very short reflecting a diffusion of temperature from venous to arterial site. This is schematically reflected in Figure 3B. However, the second measurement (Figure 1 right curve) proves that when blood flow in the femoral or iliac vein is much higher, the injectate

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**Figure 1.** Two separate transpulmonary thermodilution measurements in the same patient using the same arterial and venous catheters.

The left curve was registered in a low cardiac output state; the right curve was registered in a normal output state. The grey area in the left curve shows the cross-talk “area”. Note the faster appearance of the temperature change after injection of the ice-cold solution in the left curve compared to the right curve (time interval from injection to A in left curve compared to time interval from injection to B in right curve).

\[ \text{Tblood} = \text{blood temperature registered using the PICCO catheter inserted in the femoral artery} \]

\[ \text{Tinj} = \text{injectate temperature registered in the central venous catheter inserted in the femoral vein} \]

\[ \text{A} = \text{cross-talk temperature peak} \]

\[ \text{B} = \text{normal thermodilution peak} \]
is quickly transported away from the thermistor and the "cross-talk phenomenon" will not be seen in the thermodilution curve. This (normal) situation is drawn in Figure 3A.

The second case demonstrates that in instances of a very low cardiac output, the cross-talk phenomenon can occur even if the two invasive catheters are not in close proximity. In this case, as a result of the extremely low blood flow in the inferior caval vein the injectate was able to diffuse to the aortic blood and in this way "cool down" the arterial thermistor. This is shown in Figure 3C. When the catheter was advanced to the right atrial position this phenomenon disappeared.

In order for the transpulmonary thermodilution technique to measure cardiac output reliably, all of the following assumptions have to be met: 1) constant blood flow, 2) no or minimal loss of indicator, 3) complete mixing of the indicator with blood, and 4) the indicator may only pass the thermistor once [8]. Since in both of the described cases Assumption 4 was not met the measurements had to be discarded. Furthermore, it is debatable whether Assumption 1 was met. These cases demonstrate that essential knowledge of the thermodilution technology is required for correct interpretation of the measurements [9–11].

These situations may occur more often than suspected. In a recent study we evaluated 115 measurements of transpulmonary thermodilution in 27 children. After careful analysis of the stored dilution curves, at least four instances of the cross-talk phenomenon were observed (> 3%). It is therefore advisable for the manufacturer to implement an algorithm that analyses the thermodilution curve and produces a warning if the cross-talk phenomenon is suspected. This algorithm might be based upon a biphasic dilution curve together with a short time interval between injection and first appearance of a temperature change by the arterial thermistor.

The reliable use of the TPTD technique with a femoral central

![Figure 2. Example of two separate transpulmonary thermodilution measurements in a monkey.](image)

The left curve was registered with the venous injection point in the inferior caval vein position while the right curve was registered in the same haemodynamic situation but with the injection point in the right atrial position.

![Figure 3. Schematic view of the two mechanisms of the cross-talk phenomenon](image)

A = normal flow state with thermal indicator injection in iliac vein
B = low flow state with thermal indicator injection in iliac vein, the indicator diffuses to the iliac artery
C = low flow state with thermal indicator injection in inferior caval vein, the indicator diffuses to the aorta
CVC = central venous catheter
AC = Arterial catheter
Ao = aorta
ICV = Inferior caval vein

$t_{\text{blood}} =$ blood temperature registered using the PICCO catheter inserted in the femoral artery

$T_{\text{inj}} =$ injectate temperature registered with a central venous catheter inserted in inferior caval position (left curve) or right atrial position (right curve)

A = cross-talk temperature peak
B = normal thermodilution peak
venous catheter has been described in adults and children [12,13]. In order to prevent the occurrence of the cross-talk phenomenon in this situation, it has been advised to use longer central venous catheters for the femoral route [14]. However, this does not completely prevent this problem in situations of very low blood flow as was shown in Case 2. Therefore in the upper part of the body, a central venous line is preferred.

We conclude that when carrying out TPTD measurements with arterial and venous catheters both positioned in the lower body, the thermodilution curve should always be closely monitored for a biphasic shape, especially when the cardiac output is low and when the catheters are in close proximity. It is recommended that the manufacturer should develop an algorithm that produces a warning in these instances.

**References**