

PiCCO and LiMON Top Recommended Literature

PiCCO Technology

Transpulmonary Thermodilution Review Articles

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Transpulmonary Thermodilution Review Articles

Sakka SG, Reuter DA, Perel A

The transpulmonary thermodilution technique

J Clin Monit Comput 2012; 26: 347-53

In this article the authors discuss / describe the following;

1. This is a comprehensive review of the thermodilution technique as used by the PiCCO technology. The transpulmonary thermodilution technique (TPTD) is described as a safe, multi-parametric advanced cardiopulmonary monitoring technique that provides important parameters required for making decisions in critically ill patients.
2. The TPTD provides more reliable indicators of preload than filling pressures, the unique measurement of extravascular lung water (EVLW) and comparable accuracy in measuring cardiac output (CO). Intermittent measurement of the CO by TPTD when coupled with pulse contour analysis, offer automatic calibration of continuous CO, as well as accurate assessment of volumetric preload, fluid responsiveness and EVLW.
3. Advanced analysis of the thermodilution curve is described as are all the corresponding parameters.
4. TPTD-guided algorithms have been shown to improve the management of high-risk surgical and critically ill patients.

In this review the author discusses / describes the following:

1. This comprehensive review of the PiCCO Technology provides a summary of the thermodilution and continuous parameters with particular focus on the potential for improved patient outcome when treatment is guided by extravascular lung water.
2. The complexity of hemodynamic optimization is highlighted. From this background the PiCCO monitor is described as an “all inclusive” alternative to current hemodynamic monitors and is very important in the management of hemodynamically unstable patients in the operating room or ICU.
3. The author goes on to discuss the dynamic parameters (pulse pressure variation, stroke volume variation) along with their limitations for assessing volume responsiveness.
4. The transpulmonary thermodilution method for ascertaining cardiac output is then described along with pulse contour analysis and the pulse contour algorithm which is described as reliable and accurate even during hemodynamic instability.
5. The calculation of extravascular lung water (EVLW) as a surrogate marker for pulmonary edema, and global end-diastolic volume as a volumetric preload index, via the thermodilution technique is discussed in detail.
6. The limitations of the thermodilution method are listed including vascular obstruction, effect of PEEP, focal lung injury and lung resection. Complications of PiCCO monitoring are also mentioned including the need to access a “large” artery. However, the unreliability of the radial site for arterial pressure monitoring is highlighted. In particular the current perception amongst clinicians that the radial artery is the safest site is disputed citing the scientific literature.
7. Finally the diagnostic, prognostic and therapeutic value of EVLW is discussed in detail listing the various studies that have shown the usefulness of EVLW measurement to titrate treatment on an individual basis which may improve outcome.

Severe Burns

Bognar Z, Foldi V, Rezman B, Bogar L, Csontos C.

Extravascular lung water index as a sign of developing sepsis in burns

Burns 2010; 36(8): 1263-70

In this article the authors discuss / describe the following:

1. The records from 28 patients with total burned surface area >20% were analysed.
2. Various parameters including EVLW, Intrathoracic Blood Volume Index (ITBVI), positive end-expiratory pressure (PEEP), Baltimore Sepsis Scale (BaSS) and the blood test procalcitonin (PCT) as a marker of sepsis were recorded. EVLWI only matched with PCT on day 0 of the development of sepsis.
3. Statistical analysis showed that an EVLW >9 on the day before the development of the sepsis was highly predictive for the forthcoming development of the sepsis.
4. After antibiotic treatment EVLWI remained high in non-survivors, decreased in survivors, whereas PCT decreased in both groups.
5. The authors suggest that EVLWI is an early warning sign of developing infection and its continuous elevation can predict poor prognosis in burn patients.

Csontos C, Foldi V, Fischer T, Bogar L.

Arterial thermodilution in burn patients suggests a more rapid fluid administration during early resuscitation.

Acta Anaesthesiol Scand 2008; 52(6): 742-9

In this article the authors discuss / describe the following:

1. This study compared the effect of two different types of fluid resuscitation regimes (fluid intake based on urine output compared to fluid administration based on a PiCCO intrathoracic blood volume index) on multi organ dysfunction and central venous oxygen saturation (ScvO₂ from the CeVOX) in early resuscitation in burn patients.
2. 24 patients with more than 15% burns to their body surface area were included in the study and randomized to receive either fluid resuscitation guided by their hourly urine output (HUO) or fluid resuscitation guided by the intrathoracic blood volume index (ITBVI) from the PiCCO.
3. All patients were monitored with both the PiCCO and the CeVOX Technologies.
4. The ScvO₂ was significantly lower in the hourly urine output group which corresponded to a significantly higher incidence of multiple organ failure, than the PiCCO ITBVI group.
5. The authors describe the PiCCO preload parameter ITBV as the better target parameter for resuscitation of the severely burned patient post injury (due to less organ failure).

Cardiogenic Shock

Ritter S, Rudiger A, Maggiorini M

Transpulmonary thermodilution derived cardiac function index identifies cardiac dysfunction in acute heart failure and septic patients: an observational study

Crit Care 2009; 13(4): R133

In this article the authors discuss / describe the following:

1. This study compared the cardiac function (including contractility) as measured by the PiCCO and the pulmonary artery catheter (PAC) in patients with acute heart failure or severe sepsis / septic shock.
2. Twelve patients with acute heart failure (AHF) and 9 patients with severe sepsis or septic shock admitted to a medical intensive care unit were included in the study.
3. All patients had both a PiCCO catheter and PAC inserted and four simultaneous hemodynamic measurements were made during a 24 hour observation period.
4. Compared to septic patients, AHF patients had a significantly lower cardiac index, cardiac function index (CFI), global ejection fraction (GEF), mixed venous oxygen saturation (S_{mvO2} from the PAC) and pulmonary vascular permeability index, but higher pulmonary artery occlusion pressure. All patients with a CFI < 4.5 min⁻¹ also had a S_{mvO2} ≤ 70%.
5. In both groups, the CFI from the PiCCO correlated with the PAC left ventricular stroke work index and cardiac power thereby validating this contractility parameter.
6. The authors conclude that in critically ill medical patients, assessment of cardiac function using the PiCCO-Technology is an alternative to the PAC. A low CFI identifies cardiac dysfunction in both AHF and septic patients.

Friesecke S, Heinrich A, Abel P, Felix SB.

Comparison of pulmonary artery and aortic transpulmonary thermodilution for monitoring of cardiac output in patients with severe heart failure: validation of a novel method.

Crit Care Med 2009; 37(1): 119-23

In this article the authors discuss / describe the following:

1. 29 patients with severe heart failure were included in the study. Patients had both a PiCCO catheter and PA catheter inserted.
2. The patients had left ventricular ejection fraction of <35% and symptoms of heart failure (New York Heart Association class III-IV).
3. Thermodilution measurements were made for both the PiCCO and PAC at the same time, when clinically necessary.
4. A total of 325 data pairs were analyzed. The average CO of both methods was 4.4 L/min (CI 2.0). The percentage error was 27.3% below the acceptable level of 30% as defined previously.
5. The authors conclude that in patients with severely impaired left ventricular function (severe heart failure), measurement of CO by the PiCCO provides valid results.

Paediatrics

Kraft R, Herndon DN, Branski LK, Finnerty CC, Leonard KR, Jeschke MG

Optimized fluid management improves outcomes of pediatric burn patients

J Surg Res 2012; epub

In this paper the authors discuss / describe the following:

1. One of the major determinants for survival of the severely burned patient is appropriate fluid resuscitation. Normally fluid resuscitation is calculated on body weight or body surface area, burn size, and urinary output. However, recent evidence suggests that this fluid calculation is inadequate and both under and over resuscitation has increased morbidity and mortality.
2. The authors tested fluid administration optimization during the critical initial phase guided by the PiCCO (using cardiac index, intrathoracic blood volume and extravascular lung water) in 76 severely burned pediatric patients and compared their outcomes to 76 conventionally monitored patients (using urine output to guide fluid resuscitation).
3. Clinical hemodynamic measurements, organ function and biomarkers were recorded for the first 20 days after burn injury.
4. Patients in the PiCCO group received significantly less fluids with similar urinary output, resulting in a significantly lower positive fluid balance. The central venous pressure in the PiCCO group was maintained in a more controlled range which was associated with a significantly lower heart rate and significantly lower incidence of cardiac and renal failure.
5. The authors conclude that fluid resuscitation guided by the PiCCO during hospitalization represents an effective treatment and is associated with beneficial effects on postburn morbidity.

Lemson J, Backx AP, van Oort AM, Bouw TP, van der Hoeven JG.

Extravascular lung water measurement using transpulmonary thermodilution in children

Pediatr Crit Care Med 2009; 10(2): 227-33

In this study the authors discuss / describe the following:

1. This study validated the accuracy of single transpulmonary thermodilution extravascular lung water (EVLW) measurement (as used by the PiCCO-Technology) in small children. 12 children (<2 yrs or <12 kg) admitted to the Catheterization Laboratory of a university hospital were included in the study and instrumented with the COLD device (previous device to the PiCCO Technology).
2. The COLD device uses cold indocyanine green for the thermodilution measurement and is considered to be the gold standard clinically for the measurement of EVLW.
3. Measurements were performed using injections of ice-cold ICG indicator for the COLD measurements and ice-cold saline to provide the measurement as utilized by the PiCCO Technology.
4. The authors found that the measurement of EVLW using the COLD closely related to the measurement of EVLW as used by the PiCCO-Technology ($p < 0.0001$). Statistical analysis for the two comparative EVLW measurements showed a mean bias of 2.34 mL/kg (18.13%) and limits of agreement ± 2.97 mL/kg (19.78%), well below the previously defined acceptable level of 30%.
5. The authors conclude that clinical measurement of EVLW in young children can be performed using the PiCCO-Technology. They also confirm that the central venous line placed femorally provides accurate EVLW measurements. They conclude that this technique is a powerful tool for clinicians to guide fluid therapy and distinguish between capillary leakage or hydrostatic edema.

Paediatrics

Lemson J, Merkus P, van der Hoeven JG

Extravascular lung water index and global end-diastolic volume index should be corrected in children

J Crit Care 2011; 26(4): 432 e7-432 e12

In this article to authors describe / discuss the following:

1. The aim of the present study was to explain why extravascular lung water index (EVLWI) is higher and why global end-diastolic blood volume index (GEDVI) is lower in young children when measured with the PiCCO system.
2. In this study the authors pooled available data including age, height, body weight, body surface area, heart and lung weights from literature concerning children.
3. From the available data the following were calculated; lung weight-to-body weight ratio, the heart weight-to-BSA ratio, and the end-diastolic volume-to-BSA ratio. These were then compared to the ratios to body growth and development.
4. From this data it was discovered that lung weight develops more slowly and with less speed than body weight. In addition, the (relatively) greater lung weight in younger children results in a higher amount of pulmonary blood volume. This explains the higher EVLWI in young children.
5. End-diastolic blood volume and heart weight increase more quickly. This explains the lower GEDVI in young children.
6. The authors propose correction factors for comparing EVLWI and GEDVI with the adult reference values.

Septic Shock

Chung FT, Lin HC, Kuo CH, Yu CT, Chou CL, Lee KY, Kuo HP, Lin SM.

Extravascular lung water correlates multiorgan dysfunction syndrome and mortality in sepsis.

PLoS One 2010; 5(12): e15265.

In this article the authors discuss / describe the following:

1. This study investigated whether increased extravascular lung water index (EVLWI) correlated with multiple organ dysfunction syndrome (MODS) and mortality in sepsis. Sixty-seven patients with severe sepsis were included in the study and data collected to see if there was an association between EVLWI and the development of MODS and mortality.
2. EVLWI levels were higher in septic patients with MOD on day 1 than in those without MOD.
3. Statistical analysis showed that EVLWI could predict whether the patient was going to develop MOD. In fact EVLWI levels could predict both MODS and mortality during the ICU stay.
4. The authors conclude that increased EVLWI levels are associated with the development of MODS and mortality during the patients' ICU stay.

Martin GS, Eaton S, Mealer M, Moss M.

Extravascular lung water in patients with severe sepsis: a prospective cohort study

Crit Care 2005; 9(2):R74-82

In this article the authors discuss / describe the following:

1. 29 patients with severe sepsis were included in the study, 86% were mechanically ventilated. 52% of the patients developed acute respiratory distress syndrome (ARDS).
2. Patients who had a high EVLWI had a worse survival than those who had low EVLWI and those with low EVLWI had a better survival even if ARDS was present.
3. Patients with chronic alcohol abuse had a higher EVLWI.
4. There was a low correlation of EVLWI with chest x ray.
5. The authors suggest that as some patients had high EVLWI but no clinical criteria of ARDS, EVLWI may be a sensitive tool for detecting subclinical lung injury.
6. The authors suggest that EVLWI may allow earlier diagnosis of lung injury and should be included in the ARDS definitions and that it may serve to risk stratify sepsis patients and to improve patient management.

Liver Surgery

Costa MG, Girardi L, Pompei L, Chiarandini P, De Flaviis A, Lugano M, Mattelig S, Tripi G, Vetrugno L, Baccarani U, Scudeller L, Della Rocca G

Perioperative intra- and extravascular volume in liver transplant recipients

Transplant Proc 2011; 43(4): 1098-102

In this article the authors discuss / describe the following:

1. Assessing adequate volemia to avoid fluid overload and pulmonary edema perioperatively in liver transplantation (LT) is a challenge both for the anesthetist and the intensivist.
2. Volumetric preload indices, such as intrathoracic blood volume index (ITBVI), measured by PiCCO transpulmonary thermodilution, and continuous end-diastolic volume index (EDVI), measured by pulmonary artery thermodilution, were shown to better reflect preload than central venous pressure (CVP) or pulmonary artery occlusion pressure (PAOP). An ITBVI increase soon after the graft reperfusion influenced pulmonary perfusion without an alteration of extravascular lung water index (EVLWI) and without impaired oxygenation.
3. This study was designed to evaluate relationships between CVP, PAOP, ITBVI, EDVI, and stroke volume index (SVI) within 48 hours after LT. We also investigated the relationship between EVLWI and arterial partial pressure of oxygen and inspired oxygen fraction ratio ($\text{PaO}_2/\text{FiO}_2$).
4. 125 patients were enrolled undergoing LT. All patients were monitored with the PiCCO system (Pulsion Medical System) and with advanced pulmonary artery catheter connected to the Vigilance System. Hemodynamic-volumetric data were collected upon intensive care unit admission and every 8 hours up to 48 hours.
5. Univariate and multivariate regression models were fitted to assess associations between SVI and EDVI, ITBVI, and filling pressures after adjusting for the right ventricular ejection fraction (RVEF, categorized as ≤ 30 , 31-40, or > 40) and the phase of the observation period. We also assessed associations between $\text{PaO}_2/\text{FiO}_2$ and EVLWI.
6. SVI was associated with EDVI, ITBVI, and RVEF. The models showing the best fit to the data were those including EDVI and ITBVI. Neither CVP nor PAOP showed correlation with SVI. EVLWI inversely correlated with $\text{PaO}_2/\text{FiO}_2$.
7. In the first 48 hours after LT, ITBVI and EDVI were associated with SVI assessment, whereas CVP and PAOP were not related. EVLWI significantly inversely correlated with $\text{PaO}_2/\text{FiO}_2$.

ALI/ARDS

Letourneau JL, Pinney J, Phillips C

Extravascular lung water predicts progression to acute lung injury in patients with increased risk.

Crit Care Med 2012; 40(3): 947-54

In this article the authors discuss / describe the following;

1. In this study the PiCCO extravascular lung water index (EVLWI) was used to predict acute lung injury (ALI) in high risk patients. 29 patients who either had ALI or where at risk of developing ALI had their EVLWI measured for 5 days by the PiCCO. They also had other markers of disease severity recorded.
2. The EVLWI on day 1 for patients who progressed to ALI was higher than for those who did not progress to ALI (15.5 vs. 8.7 ml/kg). None of the other parameters were able to predict the progression to ALI as strongly.
3. EVLWI also predicted progression to ALI 2 days sooner than the patients officially met the American European Consensus Committee criteria for ALI.
4. An EVLWI value on day 1 of 10 ml/kg was most able to predict progression to ALI. There was no difference in EVLWI between those who progressed to ALI vs. those who already had ALI (14 vs. 15 ml/kg).
5. This study shows that an elevated EVLWI is a feature of early ALI and discriminates between those with ALI and those without. Furthermore, EVLWI predicts progression to ALI in patients 2.6 days before patients met the official criteria for it. These 2.6 days may represent a missed opportunity for a therapeutic intervention and improved outcome.

Monnet X, Anguel N, Osman D, Hamzaoui , Richard C, Teboul JL

Assessing pulmonary permeability by transpulmonary thermodilution allows differentiation of hydrostatic pulmonary edema from ALI / ARDS

Intensive Care Medicine 2007; 33 (3): 448-53

In this article the authors discuss / describe the following;

1. The authors looked at the records of 48 critically ill patients with acute respiratory failure and pulmonary edema (extravascular lung water greater than 12 ml/kg).
2. They noted the PVPI from the PiCCO and the ratio of EVLW over Global End-diastolic Volume Index (GEDVI).
3. Three expert doctors then reviewed the patients clinical notes and test results (except for the above PVPI and GEDVI) and stated what they thought the cause of the pulmonary edema was.
4. In patients identified as having pulmonary edema caused by ALI /ARDS the PVPI was, on average, 4.7 and in patients identified as having pulmonary edema caused by cardiac failure it was only 2.1. This difference was statistically significant.
5. The authors state that a PVPI ≥ 3 is highly sensitive and specific for an accurate diagnosis of pulmonary oedema caused by ALI /ARDS.

Neurosurgery

Mutoh T, Kazumata K, Ishikawa T, Terasaka S.

Performance of Bedside Transpulmonary Thermodilution Monitoring for Goal-Directed Hemodynamic Management After Subarachnoid Hemorrhage.

Stroke 2009; 40(7); 2368-74

In this study the authors describe / discuss the following:

1. This study looked at the effectiveness of PiCCO guided early goal-directed hemodynamic therapy in patients with vasospasm after subarachnoid hemorrhage (SAH), a condition that requires careful fluid management to try and optimize blood flow to the brain without causing side effects such as pulmonary edema, or cardiac failure.
2. One hundred and sixteen patients with subarachnoid hemorrhage who had had surgical clipping of the point of bleeding were included in the study. Sixteen patients with vasospasm were monitored with both the PiCCO and Pulmonary Artery Catheter (PAC) and their cardiac outputs (CO) compared. The preload value from the PiCCO (global enddiastolic volume GEDI) was also compared to the pulmonary capillary wedge pressure (PCWP) or central venous pressure (CVP).
3. The following 100 patients were randomized to receive either PiCCO or PAC guided goal directed care.
4. Both the thermodilution and continuous CO's from the PiCCO were found to closely agree with the reference CO from the PAC (correlation of $r=0.85$ and 0.77 and low percentage error 13.5% and 18.0%).
5. The authors found overwhelming evidence of the benefit of the goal directed therapy driven by the PiCCO over the PAC including the following;
 - a) The time to establish the CI goal of ≥ 3.5 for patients with vasospasm was quicker in the PiCCO group (3 days versus 4 days in the PAC/CVP group).
 - b) Fluid responsiveness was predicted better with GEDI than with PCWP and CVP.
 - c) Importantly patients who received early goal directed management with the PiCCO had reduced frequencies of vasospasm (50 vs 60%) and cardiopulmonary complications compared with those managed with standard therapy (2% vs 12%), $P<0.05$.
 - d) Vasospasm related cerebral infarction (death of brain tissue caused by spasm of the blood vessels in the brain), a serious complication of SAH, was reduced in the PiCCO group (6 vs 14%).
 - e) The functional outcome of the patients at 3 months, although not statistically significant, trended towards more favorable outcomes in the PiCCO group.

Cardiac Surgery

Goepfert M, Reuter D, Akyol D, Lamm P, Kilger E, Goetz A

Goal directed fluid management reduces vasopressor and catecholamine use in cardiac surgery patients

Intensive Care Medicine 2007; 33; 96-103

In this article the authors describe/discuss the following:

1. This important article describes how using the PiCCO-Technology parameters (global end-diastolic volume index – GEDVI and Extravascular lung water - EVLWI) to guide goal-directed fluid management can impact very positively on outcome in cardiac surgery patients.
2. The authors introduced an algorithm based on PiCCO parameters for treating patients having cardiac bypass surgery. They compared the outcome in 40 patients before the introduction of the treatment algorithm (control group) to 40 patients after the treatment change (Goal Directed Therapy - GDT Group).
3. In the GDT group the treatment was guided by an algorithm based on the GEDVI and EVLWI to maintain an adequate Cardiac Index and mean arterial pressure (MAP).
4. The control group was treated according to normal practice and the doctors usual treatment (based on Central Venous Pressure and MAP).
5. In the GDT group the use of drugs to support the blood pressure was much shorter and the number of drugs required was less. This is important because the use of these types of drugs can have serious side effects. The GDT group also received more fluids.
6. Highly significant was the finding that the duration of mechanical ventilation was 3 hours less and the time to the patient being fit for discharge was 8 hours shorter in the GDT group. When this is applied to a number of patients there is a potential for significant cost savings because of the shorter ICU stay.

LiMON Technology

Intensive Medicine

Inal MT, Memis D, Kargi M, Sut N.

Prognostic value of indocyanine green elimination assessed with LiMON in septic patients

J Crit Care 2009; 24(3): 329-34

The objective of this study was to compare the value of the indocyanine green plasma disappearance rate (ICG-PDR) from the LiMON-Technology with the commonly used scoring system for illness severity, the APACHE II score, in critically ill septic patients.

In this article the authors discuss / describe the following;

1. The data from 40 septic patients was analysed and the ICG-PDR and APACHE II score compared.
2. Statistical analysis showed that ICG-PDR was significantly lower in non-survivors than survivors (12% versus 21%).
3. The ICG –PDR was found to be more accurate for predicting outcome than the APACHE II score (0.765 versus 0.692).
4. Mortality was 80% in patients with an ICG-PDR below 8%.

This paper has confirmed the clinical usefulness of the ICG–PDR as a good predictor of survival in septic patients that is available at the bedside.

Liver Transplantation

Olmedilla L, Perez-Pena JM, Ripoll C, Garutti I, de Diego R, Salcedo M, Jimenez C, Banares R.
Early noninvasive measurement of the indocyanine green plasma disappearance rate accurately predicts early graft dysfunction and mortality after deceased donor liver transplantation
Liver Transpl 2009; 15(10): 1247-53

This study looked at the relationship between the indocyanine green plasma disappearance rate (ICGPDR from the LiMON Technology) and early graft function after liver transplantation. They also evaluated the role of ICGPDR in the prediction of severe graft dysfunction.

In this study the authors describe / discuss the following;

1. 172 liver transplants from deceased donors were analyzed. Ten of these patients had severe graft dysfunction, 6 received a second transplant and 4 died while waiting for new grafts.
2. PDR as an estimate of early graft function was measured 1 hour and within the first 24 hours after reperfusion. The PDR was significantly lower in the severe graft dysfunction (SGD) group and was an excellent predictor of SGD.
3. A threshold PDR value of 10.8%/min at 1 hour and 10%/min at 24 hrs was highly statistically accurate for predicting SGD.
4. In addition survival was significantly in patients with lower PDR at 3, 6 and 12 months after surgery.
5. The authors conclude that very early measurement of ICGPDR can accurately predict severe graft dysfunction and mortality after liver transplantation.

This study has shown that very early measurement of ICGPCR with the LiMON can accurately predict problems and mortality after donor liver transplantation. Using this test helps design appropriate therapeutic interventions in this complicated clinical situation.

Liver Resection

Scheingraber S, Richter Sn Igna D, Flesch S, Kopp B, Schilling MK.

Indocyanine green disappearance rate is the most useful marker for liver resection

Hepatogastroenterology 2008; 55(85): 1394-9

This study compared indocyanine green plasma disappearance rate (ICG PDR) obtained with the LiMON with the more conventional liver function blood tests pre and post liver resection to see which was most accurate for identifying patients at risk of developing complications post surgery for removal of part of the liver.

In the article the authors discuss / describe the following:

1. 96 patients undergoing liver resection were included in the study. Classical liver function markers, bilirubin and prothrombin time were recorded along with ICG PDR pre and post surgery.
2. Statistical analysis (Receiver Operator Curves) were performed to assess the value of each parameter for detecting post operative liver failure and dysfunction.
3. The authors found that the ICG PDR and prothrombin time taken preoperatively could differentiate between patients with and without cirrheses. Post operatively those with cirrhosis did not recover to preoperative values.
4. The ICG PDR was found to be most accurate for indicating post operative liver dysfunction. Post operative liver dysfunction could be predicted with a cut off ICG PDR level of 12.6%/min.
5. The authors recommend that ICG PDR should be measured preoperatively and daily after liver resection in all patients at risk (defined as patients with underlying liver disease, and / or requiring removal of more than 30% of the whole liver).

This study has highlighted the benefit of the LiMON PDR for identifying patients at risk of liver failure and dysfunction post surgery thereby allowing medical staff the opportunity of earlier diagnosis and earlier treatment in at risk patients.