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Abstracts of the submitted papers

Integration of inspiratory and expiratory intra-abdominal pressure: a novel concept looking at mean intra-abdominal pressure

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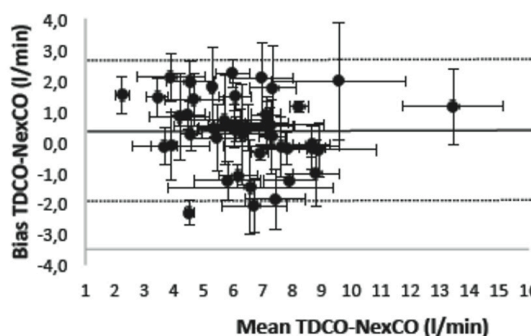
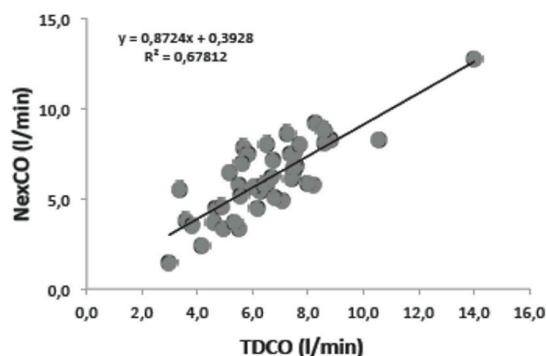
Introduction The intra-abdominal pressure (IAP) is an important clinical parameter that can significantly change during respiration. Currently, IAP is recorded at end-expiration (IAP_{ee}), while continuous IAP changes during respiration (Δ IAP) are ignored. Herein, a novel concept of considering continuous IAP changes during respiration is presented. **Methods** Based on the geometric mean of the IAP waveform (MIAP), a mathematical model was developed for calculating respiratory-integrated MIAP (MIAP_{Pri}=IAP_{ee}+i x Δ IAP), where 'i' is the decimal fraction of the inspiratory time, and where Δ IAP can be calculated as the difference between the IAP at end-inspiration (IAP_{ei}) minus IAP_{ee}. The effect of various parameters on IAP_{ee} and MIAP_{Pri} was evaluated with a mathematical model and validated afterwards in six mechanically ventilated patients. The MIAP of the patients was also calculated using a CiMON monitor (Pulsion Medical Systems, Munich, Germany). Several other parameters were recorded and used for comparison. **Results** The human study confirmed the mathematical modeling, showing that the MIAP_{Pri} correlates well with the MIAP (R²=0.99); the MIAP_{Pri} was significantly higher than IAP_{ee} under all conditions that were used to examine the effects of changes in IAP_{ee}, the inspiratory/expiratory (I:E) ratio, and Δ IAP ($p < 0.001$). Univariate Pearson regression analysis showed significant correlations between MIAP_{Pri} and IAP_{ei} (R=0.99), IAP_{ee} (R=0.99), and Δ IAP (R=0.78) ($p < 0.001$); multivariate regression analysis confirmed that IAP_{ee} (mainly affected by the level of positive end-expiratory pressure, PEEP), Δ IAP, and the I:E ratio are independent variables ($p < 0.001$) determining the MIAP. According to a regression analysis of our patient results, the MIAP can also be calculated as $MIAP = -0.3 + IAP_{ee} + 0.4 \times \Delta IAP + 0.5 \times I:E$. **Conclusions** We believe that the novel concept of MIAP is a better representation of true IAP (especially in mechanically ventilated patients) because MIAP takes into account the IAP changes during respiration. The MIAP can be estimated by the MIAP_{Pri} equation. Since the MIAP_{Pri} is almost always greater than the classic IAP, this may have implications on end-organ function during intra-abdominal hypertension. Further clinical evaluations are necessary to evaluate the physiological aspects of the MIAP.

Nexfin® non-invasive continuous hemodynamic monitoring: validation against continuous pulse contour and intermittent transpulmonary thermodilution derived cardiac output in critically ill patients

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Introduction Nexfin® (Bmeye, Amsterdam, The Netherlands) is a completely non-invasive blood pressure and cardiac output (CO) monitor based on finger arterial pulse contour analysis. **Patients and methods** We performed

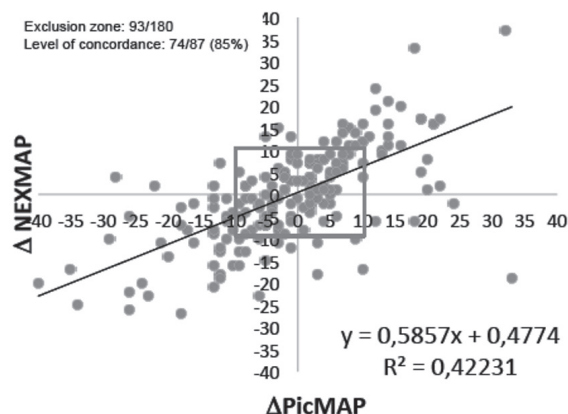


an open observational study in a mix of medical-surgical-burns critically ill patients (n=45) to validate Nexfin® against transpulmonary thermodilution and pulse contour CO (PiCCO, Pulsion Medical Systems, Munich, Germany). Nexfin® cardiac output (NexCO) and PiCCO pulse contour CO (CCO) were measured continuously and recorded at 2 hour intervals during the 8-hour study period. PiCCO thermodilution CO (TDCO) was measured at 0—4—8 hours. **Results** NexCO showed a moderate to good significant correlation with TDCO (Fig. 1) (R^2 0.68, $p < 0.001$) and CCO (R^2 0.71, $p < 0.001$). Bland and Altman analysis comparing NexCO with TDCO (Fig. 2) revealed a bias (\pm LA) of 0.4 ± 2.32 l/min (with 36% error) while analysis comparing NexCO with CCO showed a bias (\pm LA) of 0.2 ± 2.32 l/min (37% error). Subgroup analysis showed that NexCO keeps reliability in unstable septic patients with a high CO, low SVRI or on high dose of norepinephrine. NexCO is able to follow relative changes in TDCO during the same time interval (level of concordance 91%). The absolute amplitude correlation of these changes was clinically insufficient but still highly significant (R^2 0.37, $p = 0.005$). **Conclusion** in this sample of critically ill patients we found a moderate to good correlation between CO measurements obtained with Nexfin® and PiCCO. The Nexfin® could be used for keeping track of changes in CO over time. In septic patients (high TDCO/low SVRI) even with severe hypotension or on high dose norepinephrine all criteria for full interchangeability with CCO were met.

Validation study of Nexfin® continuous non-invasive blood pressure monitoring in critically ill adult patients

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Introduction Nexfin® (BMEYE, Amsterdam, The Netherlands) is a totally non-invasive blood pressure and cardiac output monitor based on finger arterial pulse contour analysis. **Patients and methods** We performed an open observational study in a mix of medical-surgical-burns critically ill patients (n=45) to validate Nexfin obtained blood pressures (NexMAP) against PiCCO (PicMAP), radial artery (RadMAP, n=17) and non-invasive intermittent sphygmomanometer (NivMAP) derived blood pressure measurements. NexMAP, PicMAP, RadMAP



and corresponding systolic (SBP) and diastolic (DBP) blood pressures were measured continuously and registered together with NivMAP with a 2 hour interval during the 8-hour study period. **Results** NexMAP shows excellent correlation with PicMAP (R^2 0.88, mean bias \pm LA -1.8 ± 10.0 mmHg, 12% error) and may be used interchangeably with invasive monitoring. NexMAP shows significant correlation with RadMAP and NivMAP but bias, limits of agreement and/or percentage error were too high to meet the criteria for interchangeability (RadMAP: R^2 0.82, mean bias \pm LA -8.1 ± 10.6 mmHg, 14% error) and (NivMAP: R^2 0.69, mean bias \pm LA -5.1 ± 20.4 mmHg, 27% error). The excellent NexMAP-PicMAP correlation was preserved in subgroup analysis for patients with severe hypotension, high SVRI, low TDCO, hypothermia and high dose of inotropics/vasopressive agents. NexMAP is able to follow changes in PicMAP during the same time interval (level of concordance 85%) (Figure 1). Nexfin SBP and DBP shows significant correlation with PiCCO, radial and non-invasive measurements but the criteria for interchangeability were not met. **Conclusion** in this sample of critically ill patients we found an excellent correlation between NexMAP and invasive obtained blood pressures by PiCCO.

Effects of continuous venovenous hemofiltration with net ultrafiltration on intra-abdominal pressure and body water distribution in septic shock patients

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Introduction Continuous veno-venous hemofiltration (CVVH) is an effective treatment for acute kidney injury (AKI) in septic shock patients. The aim of this study was to analyze the effect of CVVH with net ultrafiltration (UF) on intra-abdominal pressure (IAP), abdominal perfusion pressure (APP), fluid volume excess (VE), total body water (TBW), extracellular body water (ECW), and intracellular body water (ICW) content, and to determine whether changes in these variables were related to outcome. **Patients and methods** Adult septic shock patients treated with CVVH for AKI were studied at baseline and after 6, 12, 24, 48, 72 and 96 hours of CVVH treatment. The IAP was measured via the bladder and APP was calculated as mean arterial pressure minus IAP. Fluid volume excess, TBW, ECW and ICW were derived from whole-body bioimpedance analysis (BIA) measurements. **Results** Thirty patients were studied of whom 6 died during CVVH (non-survivors) while 24 survived. Fluid VE, TBW, ECW, ICW and IAP decreased significantly in survivors during CVVH treatment with net UF whereas these variables remained essentially unchanged in non-survivors. The APP slowly increased in survivors while it did not change in non-survivors. The IAP strongly correlated with fluid VE in survivors: the lower the IAP the lower the VE (Fig. 1.). **Conclusions** The use of CVVH with net UF successfully reduced IAP and TBW, ECW and ICW in the critically ill patients under study that survived, while APP increased. Failure to increase APP predicted fatal outcome, and finally, IAP was correlated with fluid VE.

Effect of continuous venovenous hemofiltration on plasma kynurenic acid levels in septic shock patients

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Introduction Kynurenic acid (KYNA) concentration is one of the end products of the tryptophan pathway and may be increased in patients with sepsis and trauma where it is related to adverse outcomes [1–4]. Yet, its changes have been not documented in critically ill septic shock patients with acute renal failure treated with continuous veno-venous haemofiltration (CVVH). The aim of this study was to analyze the changes in plasma KYNA concentrations in patients undergoing CVVH. Additionally, changes in plasma KYNA concentration was compared to procalcitonin (PCT), CRP and lactate. **Patients and methods** Adult septic shock patients with acute renal failure were examined. Observations were conducted at seven time points: before beginning CVVH and at 6, 12, 24, 48, 72 and 96 hours after the beginning of CVVH. Based on clinical outcomes, the data were analyzed for survivors and non-survivors. **Results** Twenty-seven patients aged 60±12 were studied. CVVH reduced plasma PCT, CRP and lactate concentration in both of the groups studied. In survivors, plasma KYNA concentration decreased from 24 hours of CVVH, whereas it was nearly unchanged in the non-survivors (Figure 1). Plasma KYNA concentration strongly correlated with plasma lactate and moderately with PCT concentrations only in survivors. **Conclusions** 1) CVVH reduced plasma PCT, CRP and lactate concentrations; 2) CVVH reduced the plasma KYNA concentration only in survivors; 3) plasma KYNA concentrations did not decrease during CVVH in non-survivor patients and 4) lack of reduction in KYNA levels may predict fatal outcomes in septic shock patients with acute renal failure who are treated with CVVH. **Acknowledgements** This abstract was presented as a paper during the ASN meeting 2012 in San Diego, CA.

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Renal replacement therapy with net fluid removal lowers intra-abdominal pressure and volumetric indices in critically ill patients

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Introduction Little is known about the effects of renal replacement therapy (RRT) with fluid removal on intra-abdominal pressure (IAP). The global end-diastolic volume index (GEDVI) and extravascular lung water index (EVLWI) can easily be measured bedside by transpulmonary thermodilution (TPTD). The aim of this study is to evaluate the changes in IAP, GEDVI and EVLWI in critically ill patients receiving slow extended daily dialysis (SLEDD) or continuous venovenous haemofiltration (CVVH) with the intention of net fluid removal. **Methods** We performed a retrospective cohort study in ICU patients who were treated with SLEDD or CVVH and in whom IAP was also measured, and RRT sessions were excluded when the dose of vasoactive medication needed to be changed between the pre- and post-dialysis TPTD measurements and when net fluid loss did not exceed 500 ml. The TPTD measurements were performed within 2 h before and after SLEDD; in case of CVVH, before and after an interval of 12 h. **Results** We studied 25 consecutive dialysis sessions in nine patients with acute renal failure and cardiogenic or non-cardiogenic pulmonary oedema. The GEDVI and EVLWI values before dialysis were 877 ml/m² and 14 ml/kg, respectively. Average net ultrafiltration per session was 3.6 l, with a net fluid loss 1.9 l. The GEDVI decreased significantly during dialysis, but not more than 47.8 ml/m² ($p=0.008$), as also did the EVLWI with 1 ml/kg ($p=0.03$). The IAP decreased significantly from 12 to 10.5 mmHg ($p<0.0001$). **Conclusions** Net fluid removal by SLEDD or CVVH in the range observed in this study decreased IAP, GEDVI and EVLWI in critically ill patients although EVLWI reduction was modest.

Extravascular Lung Water measurements in the age of obesity: which indexation to use?

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Introduction Variability of body-weight (BW) and height strongly calls for indexation of hemodynamic parameters. Extravascular lung water (EVLW) traditionally has been indexed to actual BW (BW_{act}) termed EVLW-index (EVLWI). In obese patients indexation to BW_{act} might inappropriately diminish indexed EVLW_{act}. EVLWI indexed to predicted BW (EVLW_{pred}) has been shown to better predict mortality than EVLW_{act} [1–3]. Nevertheless, data comparing the correlation of EVLW_{act} and EVLW_{pred} to pO₂/FiO₂ are inconsistent. The aim of our study was to evaluate un-indexed EVLW and EVLWI indexed to ideal BW (BW_{id}), adjusted BW (BW_{adj}), BW_{act}, BW_{pred} and height regarding pO₂/FiO₂. **Methods** In 50 patients, 696 triplicate transpulmonary thermodilutions (TPTDs) were performed using the PiCCO-system. EVLW and EVLWI were correlated to pO₂/FiO₂. Furthermore, ROC-analyses regarding pO₂/FiO₂ < 200 mmHg (primary endpoint) were performed. The findings were evaluated in an independent validation-collective (181 patients; 1426 TPTDs). **Results** In the study-collective, the largest ROC-AUCs were found for un-indexed EVLW (AUC 0.758; 95%-CI: 0.637–0.880) and EVLW_{height} (AUC 0.746; 95%-CI: 0.622–0.869). AUC for EVLW_{pred} was lower (0.713). EVLW_{act} provided the lowest AUC (0.685). These observations were confirmed in the validation-collective: EVLW_{height} provided the largest AUC (0.735), EVLW_{act} (0.710) the smallest AUC. In the merged data-pool, AUC was significantly greater for EVLW_{height} (0.729; 95%-CI: 0.674–0.784) compared to all other indexations including EVLW_{act} (ROC-AUC 0.683, $p=0.007$) and EVLW_{pred} (ROC-AUC 0.707, $p=0.0015$). **Conclusions** Indexation of EVLW/EVLWI according to BW_{act} is inappropriate with regard to the prediction of PO₂/FiO₂. EVLW_{pred} performed slightly better. EVLW_{height} and un-indexed EVLW provided the highest predictive capabilities.

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The Polycompartment Syndrome: what is the worry about?

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Introduction A compartment syndrome (CS) exists when the increased pressure in a closed anatomic space threatens the viability of enclosed and surrounding tissue [1]. Within the body there are 4 major compartments, the head, the chest, the abdomen and the extremities. Within each compartment; an individual organ or a region with multiple organs can be affected by a CS. A CS is not a disease, as such it can have many causes and it can develop within many disease processes. The abdominal compartment has some unique geographical properties, in that it is “up-stream” from the extremities and may have additive or indirect effect on lower limb compartment. In this abstract we will present a case of PCS followed by a review of the literature. **Illustrative Case Report** A 23 male was involved in a high speed motor vehicle crash. At scene and en route to hospital he was hypotensive for 40 minutes and required emergency laparotomy with splenectomy and liver packing. His sustained intracranial haematoma required an ICP monitoring. He had no limb injury. After 24 hours in the ICU, following primary fascial closure and massive transfusion, he developed Grade 4 IAH with a pressure of 28 mmHg. Both lower limbs which had not sustained primary injury were noted to be swollen, tense and anterior and posterior compartment pressures were 42 and 38 mmHg respectively. His IAP at that time was 38 mmHg. Abdominal decompression was performed together with full bilateral limb fasciotomy. At limb surgery ischaemia was noted in his lateral compartment and debridement of necrotic muscle was undertaken. While his abdominal decompression reduced both his IAP and ICP, his ICP subsequently rose and remained high for 7 days until his eventual recovery 4 weeks later. This patient is an example of secondary PCS affecting his limbs in combination with primary PCS affecting his head and abdomen. **Results** Scalea et al. was the first to introduce the term multiple compartment syndrome (MCS) in a study of 102 patients with increased intra-abdominal (IAP), intrathoracic (ITP), and intracranial pressure (ICP) after severe brain injury [2]. He suggested that the different compartments within the body are not isolated and independent entities but in stead are closely connected. Because the term multi or multiple CS is mostly used in relation to multiple limb trauma with CS needing fasciotomy and in order to avoid confusion the term polycompartment syndrome (PCS) was finally coined [3]. A recent review also draws our attention to the existence of compartment syndromes from head to toe [4]. No other literature data could be found on this topic except some recent reviews [5, 6]. More studies are therefore needed. **Take home message** An increased compartment pressure (CP) will exert a direct force on the original compartment and its contents by increasing venous resistance and decreasing perfusion pressure, but the CP will also have an effect on distant compartments. The impact on end-organ function and viability within and outside the original compartment can be devastating.

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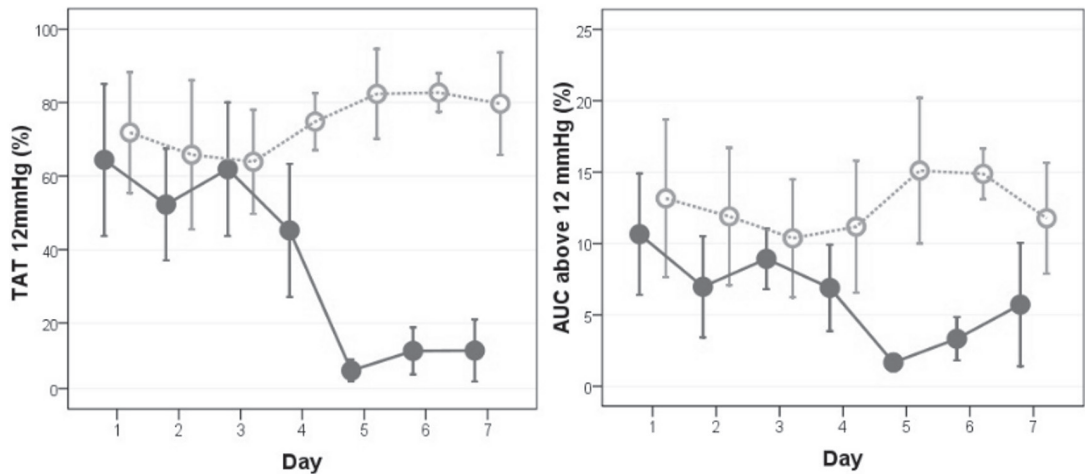
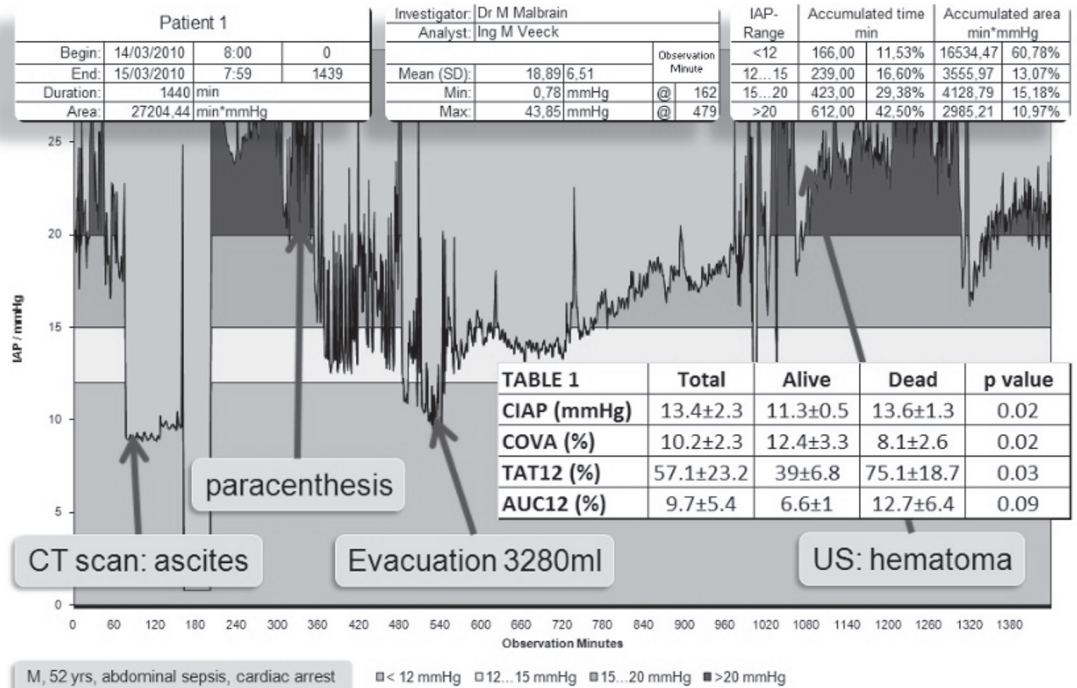
Automated computer-analysis of 24 hour abdominal pressure trends: interim results of a pilot study on the importance of area under the curve (AUC) and time above a certain threshold (TAT)

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Methods Previous studies looking at intra-abdominal-pressure (IAP) as a prognostic indicator only used intermittent-IAP (IIAP) or mean of daily obtained IIAP measurements (2 to 4 times a day) [1]. No data is available on prognostic capability of data obtained with continuous-IAP (CIAP) monitoring [2]. This study looks at novel parameters that can be obtained with CIAP and their relation to outcome. **Patients** Prospective pilot study in 10 mechanically-ventilated patients equipped with a CiMON balloon-tipped nasogastric probe

for CIAP monitoring (Pulsion Medical Systems). By means of a special software program, automated analysis of each 24 hour IAP-trend curves was performed. The area under the curve (AUC) above 12 mmHg (AUC12) was determined, together with the time above a threshold of 12 mmHg (TAT12). The coefficient-of-variation (COVA) was defined as SD/CIAP per 24 hour period. Data were recorded during the first 7 days of ICU stay and mean values (per day and per week) were analysed. **Results** The M/F ratio was 2/1, age 54 ± 14 and 5 patients died. The figure shows a CIAP-trend in a sample patient together with the automated analysis and calculation of TAT12 and AUC12. In the lower side of the figure the evolution of TAT12 and AUC12 is given as mean with error bars: from day 4, TAT12 and AUC12 were significantly lower in survivors (closed



circles). Table 1 summarizes the mean values of different mean parameters for the first week in (non) survivors: CIAP, TAT12 and AUC12 were significantly higher in nonsurvivors while COVA was lower. Although the IAP obtained at regular intervals was higher in nonsurvivors, this did not reach statistical difference. **Conclusion** CIAP monitoring offers advantages over IIAP. An automated software program allowing calculation of additional parameters (TAT12, AUC12) was able to discriminate survivors from nonsurvivors.

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Impact of body anthropomorphic parameters on baseline intra-abdominal pressure measurements in critically ill patients

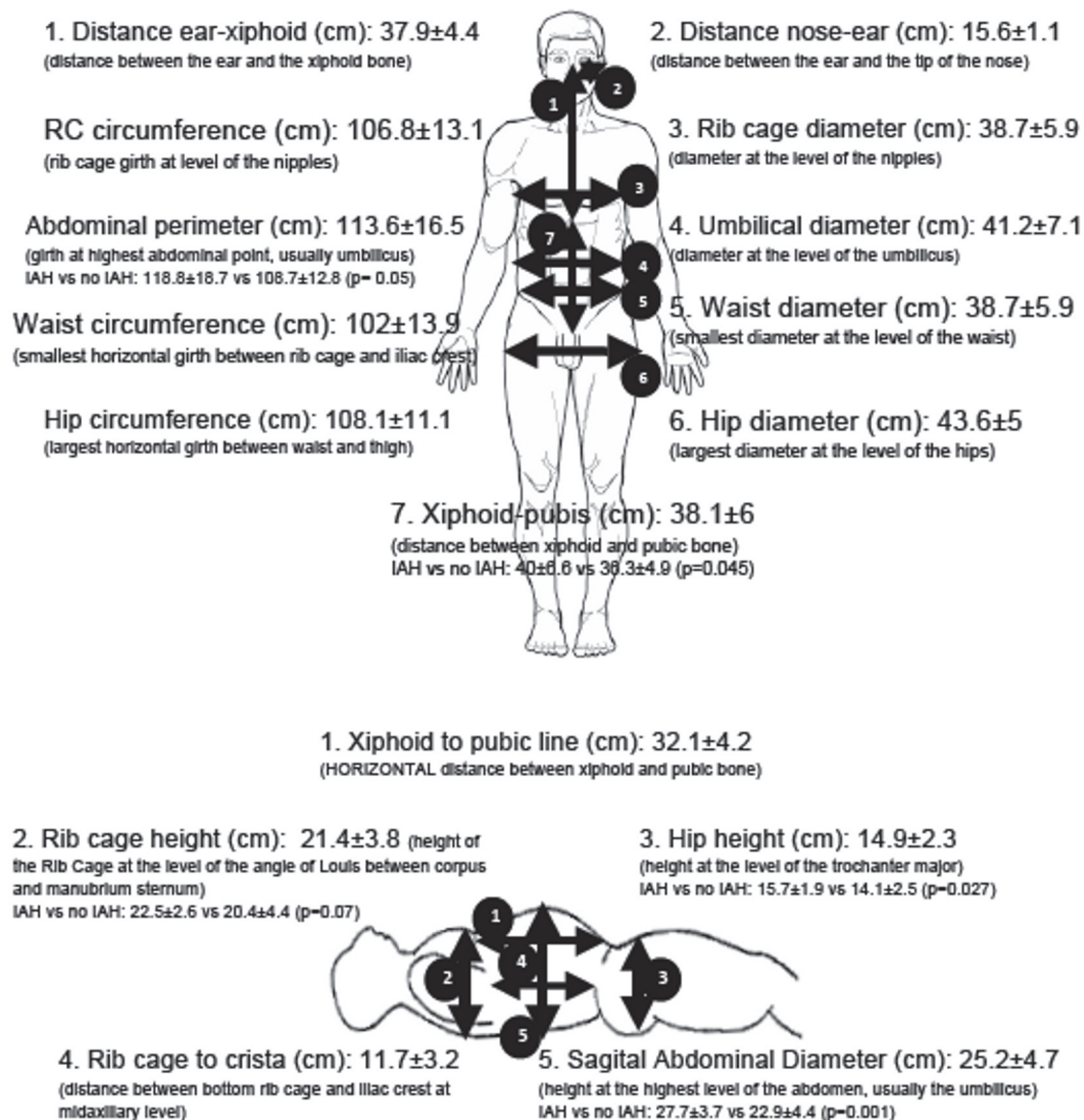
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Methods Previous studies showed a correlation between intra-abdominal pressure (IAP) and body anthropomorphic data like sagittal abdominal diameter and body mass index (BMI) [1, 2]. This study examines possible relations between other body parameters and baseline IAP measurements. **Patients and Methods** Prospective study in 45 mechanically ventilated patients equipped with a CiMON balloon-tipped nasogastric probe for continuous IAP monitoring with the possibility to record endexpiratory (IAPEe), endinspiratory (IAPEi) and mean IAP (IAP) (Pulsion Medical Systems, Munich, Germany). Intra-abdominal hypertension (IAH) was defined as a mean IAP above 12mmHg. Δ IAP was defined as IAPEe-IAPEi. Data are expressed as mean \pm SD unless stated otherwise. **Results** The SAPS-II score was 56 \pm 13; APACHE-II score was 28 \pm 11.4, and SOFA score was 11 \pm 6.3; age was 55.6 \pm 17.8 years; height 174.6 \pm 8.7 cm; weight 83.9 \pm 19.1 kg; BMI 22.7 \pm 7.5. The M/F ratio was 2/1. The IAPEi was 13.2 \pm 4.3mmHg; while IAPEe was 9.6 \pm 3.1 mmHg; mean IAP was 11.1 \pm 3.7 mmHg and Δ IAP was 3.6 \pm 1.7 mmHg.

Figure 1. summarizes the mean values of the different body parameters and the significant differences in patients with and without IAH. In patients with IAH (n=22) SAPS-II score was higher (60.8 \pm 13.4 vs 50.7 \pm 10.6;

Figure: Summary of antropomorphic data (supine position)



$p=0.015$), as was SOFA score (12.7 ± 6.8 vs 9.2 ± 5.1 ; $p=0.08$). There was a trend towards higher BMI in IAH although this was statistically not significant. 28.7 ± 9.8 vs 36.7 ± 4.2 . The Δ IAP was significantly higher in IAH: 4.6 ± 1.8 vs 2.7 ± 0.8 mmHg ($p<0.001$). We found a positive correlation between IAP and Δ IAP, suggesting a lower abdominal wall compliance (Cab) the higher the IAP: Δ IAP = $0.3183 \times$ IAP + 0.094 ($p<0.001$, $R^2=0.5211$). The female (F) patients were older ($p=0.04$), had a higher SOFA score ($p=0.026$) and higher BMI: 30.1 ± 11.7 vs 26 ± 2.9 ($p=0.05$). The Δ IAP was lower in female patients: 3 ± 1 vs 4 ± 1.9 ($p=0.023$) and they were shorter ($p<0.001$). Other observations in female patients were that they had shorter nose-to-ear ($p=0.07$) and ear-to-xiphoid ($p<0.001$) distances and a larger hip diameter ($p=0.002$) and hip circumference ($p=0.029$). **Conclusion** Patients with IAH have increased abdominal perimeter, xiphoid-to-pubis distance, rib cage height, hip height and sagittal abdominal diameter. Female patients have significantly different body anthropomorphic measurements. High IAP is related to high Δ IAP and thus a lower Cab. Body anthropomorphy probably plays a role in the Cab and the way patients behave in relation to increased intra-abdominal volume.

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Relationship between intra-abdominal pressure and indocyanine green plasma disappearance rate: hepatic perfusion may be impaired in critically ill patients with intra-abdominal hypertension

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Introduction Monitoring hepatic blood flow and function might be crucial in treating critically ill patients. Intra-abdominal hypertension is associated with decreased abdominal blood flow, organ dysfunction, and increased mortality. The plasma disappearance rate (PDR) of indocyanine green (ICG) is considered to be a compound marker for hepatosplanchnic perfusion and hepatocellular membrane transport and correlates well with survival in critically ill patients. However, correlation between PDR-ICG and intra-abdominal pressure (IAP) remains poorly understood. The aim of this retrospective study was to investigate the correlation between PDR-ICG and classic liver laboratory parameters, IAP and abdominal perfusion pressure (APP). The secondary goal was to evaluate IAP, APP, and PDR-ICG as prognostic factors for mortality. **Methods** A total of 182 paired IAP and PDR-ICG measurements were performed in 40 critically ill patients. The mean values per patient were used for comparison. The IAP was measured using either a balloon-tipped stomach catheter connected to an IAP monitor (Spiegelberg, Hamburg, Germany, or CiMON, Pulsion Medical Systems, Munich, Germany) or a bladder Foley Manometer (Holtech Medical, Charlottenlund, Denmark). PDR-ICG was measured at the bedside using the LiMON device (Pulsion Medical Systems, Munich, Germany). Primary endpoint was hospital mortality. **Results** There was no significant correlation between PDR-ICG and classic liver laboratory parameters, but PDR-ICG did correlate significantly with APP ($R=0.62$) and was inversely correlated with IAP ($R=-0.52$). Changes in PDR-ICG were associated with significant concomitant changes in APP ($R=0.73$) and opposite changes in IAP ($R=0.61$). The IAP was significantly higher (14.6 ± 4.6 vs 11.1 ± 5.3 mmHg, $p=0.03$), and PDR-ICG (10 ± 8.3 vs $15.9\pm 5.2\%$, $p=0.02$) and APP (43.6 ± 9 vs 57.9 ± 12.2 mmHg, $p<0.0001$) were significantly lower in non-survivors. **Conclusions** PDR-ICG is positively correlated to APP and inversely correlated to IAP. Changes in APP are associated with significant concomitant changes in PDR-ICG, while changes in IAP are associated with opposite changes in PDR-ICG, suggesting that an increase in IAP may compromise hepatosplanchnic perfusion. Both PDR-ICG and IAP are correlated with outcome. Measurement of PDR-ICG may be a useful additional clinical tool to assess the negative effects of increased IAP on liver perfusion and function.

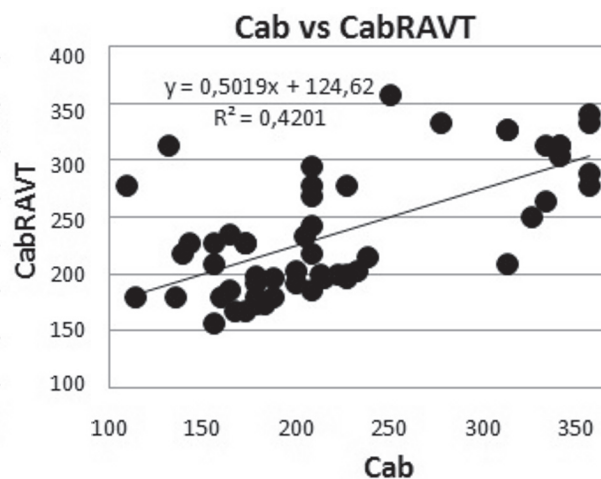
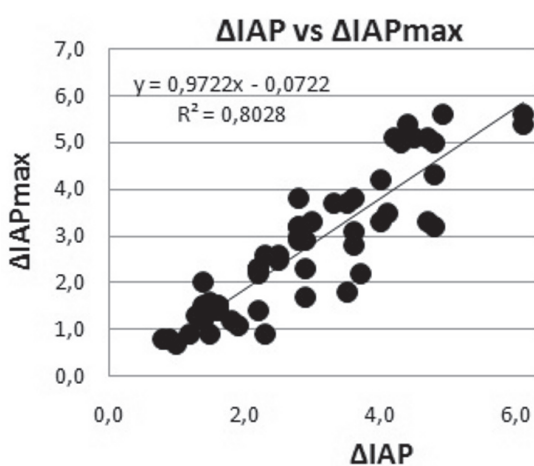
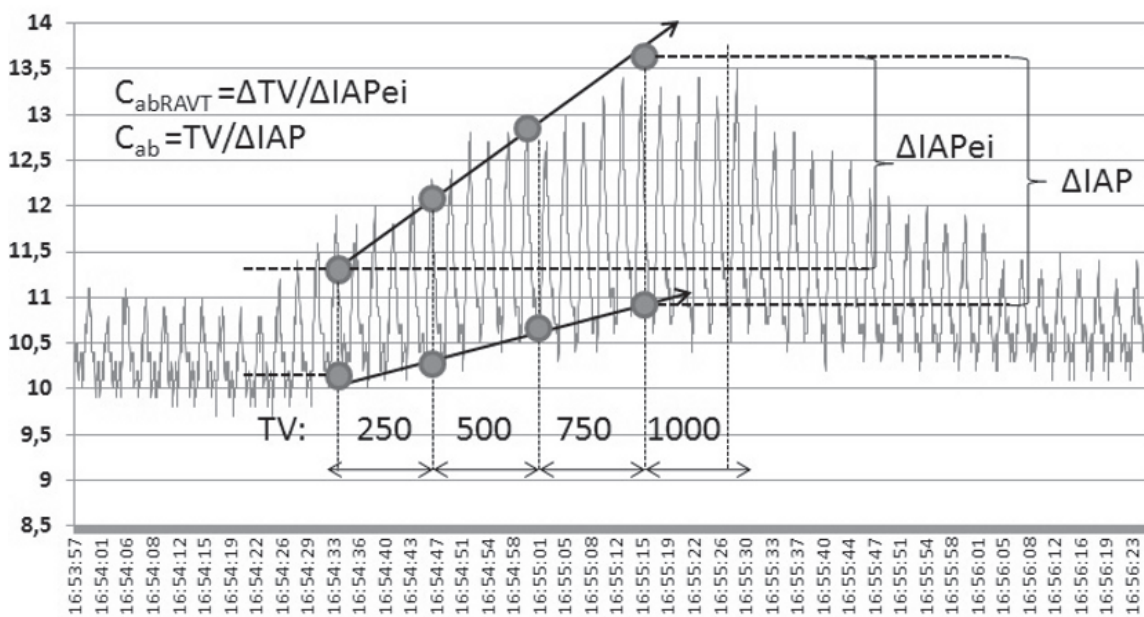
The respiratory abdominal variation test (RAVT): a noninvasive way to estimate abdominal wall compliance (Cab)

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Introduction Previous studies suggested that the respiratory variation observed in intra-abdominal pressure (Δ IAP) and defined as the endinspiratory IAP (IAPei) minus the endexpiratory (IAPee) is related to Cab in

mechanically ventilated patients. This pilot study examines the possibility of using the dynamic RAVT to estimate Cab. **Methods** Two ways of RAVT were performed in 6 mechanically ventilated patients. In the first RAVT, in IPPV-mode tidal volume (TV) was increased from 250 ml to 1000 ml (with steps of 250ml)(see Figure 1 upper panel); in the second RAVT in BiPAP-mode PEEP was increased from 0 to 15 cmH₂O keeping the same IPAP. During all settings IAPee, IAPei, mean IAP and ΔIAP were recorded. **Results** Patients were MV in IPPV mode with RR 18±3.8, Pplat 27±10.5 cmH₂O and PEEP 5 cmH₂O. The RAVT in IPPV-mode increased IAPei significantly from 10±2.5 mmHg (at TV:250) to 13.1±2.7 mmHg (at TV:1000)(*p*=0.013), mean IAP increased from 9.1±2.4 to 10.5±2.3 mmHg (*p*=NS) while IAPee remained unchanged around 8.7±2.1 mmHg. The ΔIAP increased from 1.5±0.5 to 4.3±1.1 mmHg (*p*<0.001). The overall ΔIAP was 2.9±1.3 mmHg and ΔIAPei (changes in IAPei according to changes in TV) was 2.8±1.4 mmHg. The ΔIAP correlated well with IAP (ΔIAP= 0.2912xIAP+0.0662; R²=0.3) and with ΔIAPei (ΔIAP=0.9722x ΔIAPei-0.0722; R²=0.8)(see Figure 1 lower left panel). Analysis according to Bland-and-Altman comparing ΔIAP with ΔIAPei showed a bias of 0.2±0.6 mmHg (LA -1.1 to 1.4; % error 43.7%). The Cab calculated by TV/ΔIAP correlated well with the Cab calculated with RAVT by ΔTV/ΔIAPei (Cab=0.5367 x CabRAVT+119.31; R²=0.44) (see Figure 1 lower right panel). Analysis according to Bland-and-Altman showed a bias of -16.4±54.3 (LA -125.1 to 92.3; %error 46.2%). Patients were in BiPAP-mode with RR 19.4±3.4, Pplat 28.8±4.8 and TV of 632.5±161. RAVT in BiPAP-mode significantly increased IAPee from 7.4±2.1 at PEEP=0 to 9.8±2.7 mmHg at PEEP=15 (*p*=0.05), while ΔIAP decreased from 3.4±0.7 to 2.5±1 mmHg (*p*=0.03). **Conclusion** The RAVT in IPPV-mode with increasing TVs allows noninvasively estimation of Cab. The Cab obtained with RAVT correlates with Cab obtained from ΔIAP. Increasing TVs increase IAPei while increasing PEEP increases IAPee. Future studies should look at the effects of paracentesis or laparoscopy on Cab and ΔIAP to confirm our hypothesis.



A systematic review and individual patient meta-analysis on intraabdominal hypertension in critically ill patients: The WAKE-Up! project

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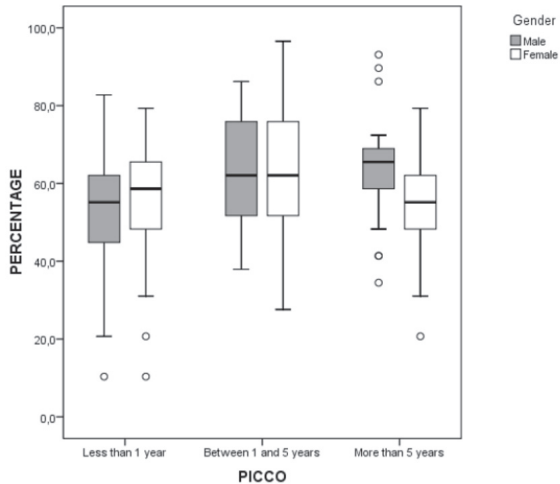
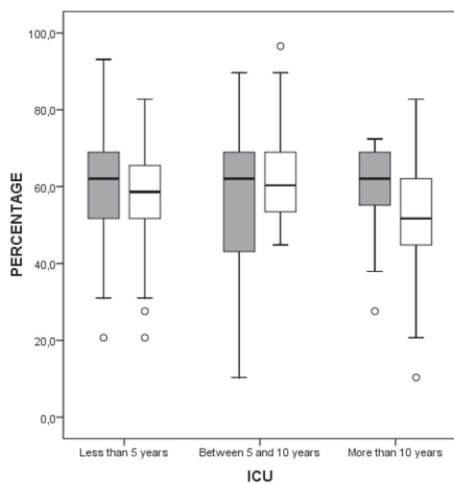
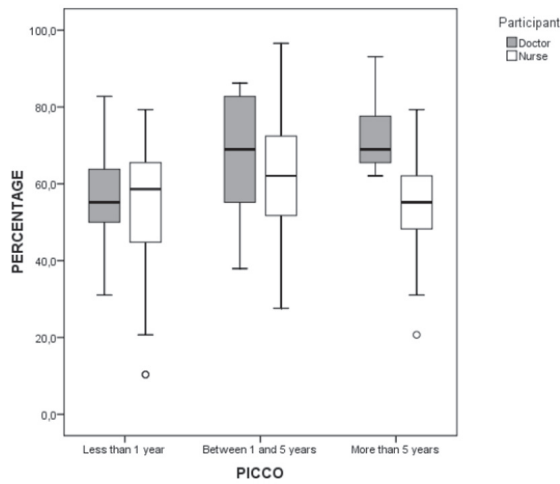
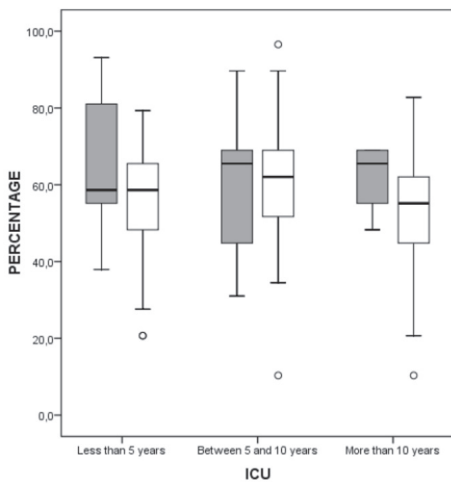
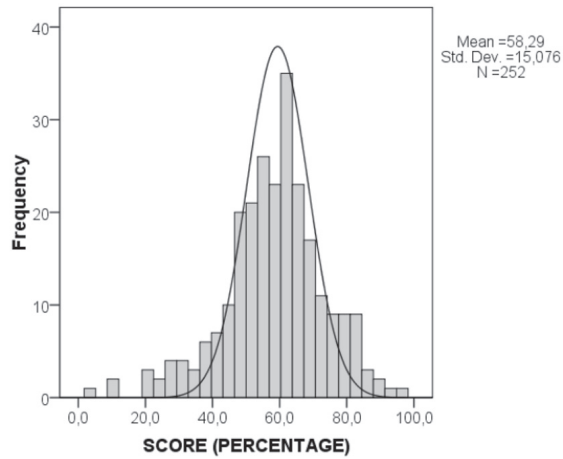
Introduction Intraabdominal hypertension (IAH), defined as a pathologically increase in intraabdominal pressure, is commonly found in critically ill patients. While IAH has been associated with numerous abdominal as well as extra-abdominal conditions, few studies have examined the occurrence of IAH in relation to mortality. The aim of this study was to evaluate the prognostic role of IAH and its risk factors at admission in critically ill patients across a wide range of settings and countries. **Methods** An individual patient meta-analysis of all available data and a systematic review of published medical databases and studies (from 1966 to June 2012) limiting the search to “clinical trials” and “randomized controlled trials”, “adults”, using the terms “intraabdominal pressure”, “intraabdominal hypertension” combined with any of the terms “outcome” and “mortality”, and of un-published data, altogether representing 21 centers from 11 countries. **Results** Data from 1669 individual patients were analyzed in the meta-analysis. Presence of IAH was defined as a sustained increase in IAP equal to or above 12 mmHg. At admission the mean overall IAP was 9.9±5.0 mmHg, with 463 patients (27.7%) presenting with IAH with a mean IAP of 16.3±3.4 mmHg. The only independent predictors for IAH were SOFA score and fluid balance on the day of admission. Five hundred thirteen patients (30.8%) died in intensive care. The independent predictors for intensive care mortality were IAH, age, SAPS II score, SOFA score and admission category. **Conclusions** This systematic review shows that IAH is frequently present in critically ill patients and it is an independent predictor for mortality.

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

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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 (0.2ml/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 $58.3 \pm 15.1\%$ (Figure 1). The doctors performed better than nurses (62.7% vs 57.0%, $p=0.012$), no difference was found 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 (Figure 2). Doctors (72.4%) performed better than nurses (54.5%) in the group of personnel with more than 5 years of PiCCO experience (Figure 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.

Conclusion 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.

Reference

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Abdominal re-intervention predictive index combined with intra-abdominal pressure (ARPI-IAP): a prognostic model to guide abdominal re-intervention in patients after abdominal surgery

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Introduction The prognosis and prediction of re-intervention after abdominal surgery is still difficult, especially when an intra-abdominal infectious complication is present. The abdominal re-intervention predictive index (ARPI), as described by Pusajó et al., [1] is a clinical score with a decision tree that can be helpful to guide the surgical treatment of these complications. In our experience, however, although the specificity of the ARPI was 100%, the sensitivity was rather low [2]. Table 1. shows the ARPI score and decision tree. On the other hand, intra-abdominal pressure (IAP) is a known independent factor related to complications and mortality in abdominal surgery. We hypothesized that the combination of IAP with ARPI in a mathematical model can add accuracy to the prognosis of re-intervention related to intra-abdominal infectious complications in patients after abdominal surgery. **Objectives** To main aim of this study was to develop a mathematical model for the prognosis and prediction of abdominal re-intervention in surgical patients with intra-abdominal infectious complications using some factors previously described (ARPI) and to evaluate the prognostic effect of adding IAP to this model. **Methods** A prospective observational study with a cohort of 300 critically ill patients after abdominal surgery, consecutively admitted at the “Calixto García” Hospital intensive care unit (ICU), between January 2008 to January 2010 (Figure 1). The patients were randomly separated in two groups (2:1), an estimation group and a validation group. The dependent variable was re-intervention, and the independent variables were the age, ARPI, IAP, type of surgery (elective or emergency) and the duration of surgery. The models were developed in the estimation group

and validated in the second group. The statistics included co-linearity analysis, outliers and binary logistic regression for the development of the models, Hosmer-Lemeshow test for the calibration and ROC curve for the discrimination. **Results** Table 2 and 3 show the indication of initial surgery and the diagnosis during the re-intervention respectively. Table 4 shows the patient demographics. Three prognostic models were developed in the estimation group: ARPI, IAP and ARPI-IAP. The common variables that were included in the three models were the age, gender, type of surgery and duration of surgery. The ARPI model (model I) integrated the ARPI to the rest of the variables aforementioned (AUC=0.925, CI 95% 0.875—0.976). The IAP model (model II) included the IAP (AUC=0.951, CI 95% 0.914—0.989) and the third model (ARPI-IAP) included also the IAP and ARPI (AUC=0.973, CI 95% 0.948—0.998). Although the three models had a good performance concerning its calibration and discrimination, the difference between the three AUC was significant ($p=0.001$). **Conclusions** The combination of different prognostic factors related to abdominal re-intervention in critically ill surgical patients in the mathematical models presented helped to predict accurately abdominal re-intervention. The ARPI-IAP model was the most accurate, followed by the IAP model. Undoubtedly, when IAP was integrated to the ARPI prognostic model for abdominal re-intervention, it had an additive effect in the prediction of re-intervention in this

Emergency surgery (at primary operation)	3	DECISION TREE 0-10 OBSERVATION 11-15 SPECIAL STUDIES Yes (Positive) Reoperation No (Negative) Observation 16-20 SPECIAL STUDIES Yes (Positive) Re-operation No (Negative) Re-operation
Respiratory failure	2	
Renal failure	2	
Ileo (from 72 h after surgery)	4	
Abdominal pain (from 48 h after surgery)	5	
Wound infection	8	
Consciousness alterations	2	
Symptoms appearing from 4th d after surgery	6	

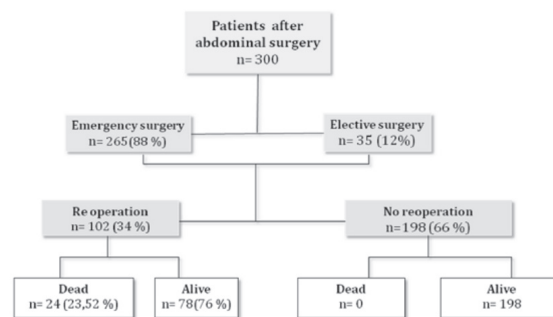


Table 2. Indication for initial surgery

Diagnosis at operation	N(%)
Colonic neoplasm	10 (3.3%)
Perforated colonic diverticulitis	18 (6%)
Intestinal obstruction	43 (14.3%)
Acute Appendicitis	111 (37%)
Perforated peptic ulcer	23 (7.7%)
Gastric cancer	6 (2%)
Acute cholecystitis	37 (12.3%)
Acute pancreatitis	3 (1%)
Gynecological peritonitis	9 (3%)
Other	40 (13.3%)
TOTAL	300 (100%)

Table 3. Findings at re-operation

Findings	N (%)
Intra-abdominal abscesses	24 (23.5%)
Generalized peritonitis	12 (11.8%)
Localized peritonitis	12 (11.8%)
Suture leakage with peritonitis	24 (23.5%)
Intestinal necrosis	3 (3.0%)
Abdominal wall necrosis with localized peritonitis	9 (8.8%)
Choleperitoneum	6 (5.9%)
No pathological findings	12 (11.8%)
Total	102 (100%)

Table 4. Patient demographics

	Estimation group n=200	Validation group n=100	p-value
Males	126 (63.0%)	62 (62.0%)	0.966 ^a
Females	74 (37.0%)	38 (38.0%)	
Age (years)	53.4 ± 19.8	58.2 ± 19.8	0.048 ^b
Comorbidity	Yes	192 (96.0%)	96 (96.0%)
	No	8 (4.0%)	4 (4.0%)
Reintervention	Yes	71 (35.5%)	31 (31.0%)
	No	129 (64.5%)	69 (69.0%)
Malignancy	Yes	9 (4.5%)	4 (4.0%)
	No	191 (95.5%)	96 (96.0%)
APACHE II score	16.5 ± 6.0	16.0 ± 5.9	0.506 ^b
Mortality	17 (8.5%)	7 (7.0%)	0.821 ^a
IAP (mmHg)	12.2 ± 5.4	12.1 ± 5.4	0.821 ^b

a: Yates corrected chi square test
b: Student "t" test

cohort of critically ill patients after abdominal surgery.

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Interim results of a prospective study on the validation of non-invasive hemodynamic monitoring with PulsioFlex in critically ill patients

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Introduction Thermodilution (TD) is considered a gold standard for the measurement of cardiac index (CI) in critically ill patients [1]. The aim of this study is to compare intermittent bolus transpulmonary TD CI (TDCI) with intermittent automatic calibration CI (AutoCI) and 2 continuous CI (CCI) obtained by pulse contour analysis with PiCCO₂ (PiCCI) and PulsioFlex (PuCCI) (Pulsion Medical Systems, Munich, Germany). **Methods** Interim results of an ongoing prospective study after inclusion of the first 20 patients (out of a targeted total population of 50 patients) with a radial line already in place (all were mechanically ventilated, and 14 were male). the age was 54.4 ± 16.7 years, BMI 28.1 ± 7.3 , SAPS-II score was 52.9 ± 13.4 , APACHE-II score was 26.7 ± 7.8 and SOFA score was 10 ± 3 . All patients underwent PiCCO monitoring (upon clinical indication and as part of escalation of hemodynamic monitoring due to instability or unclear fluid status) via a femoral line whilst the radial line was kept in place during four 8 hour time periods (in the first 2 periods the PulsioFlex was connected to the radial line, in the last two it was connected to the femoral line). In the first and third 8 hour period the PulsioFlex was calibrated with the TDCI obtained at baseline, for the second and fourth 8 hour period the PulsioFlex was calibrated with the AutoCI value. Simultaneous PiCCI and PuCCI measurements were obtained every 2 hours while simultaneous TDCI and AutoCI were obtained every 8 hours. The PiCCI and PuCCI values were recorded within 5 min before TDCI was determined by 3 repeated injections of 20ml of sterile ice-cold saline via a central venous line. We also looked at the effects of 22 interventions: passive leg raising (n=6), fluid bolus 500ml/30 minutes (n=5), increase or decrease of vasopressor (n=9), increase or decrease of dobutamine (n=1), increase in sedation (n=1). Statistical analysis was performed using Pearson correlation and Bland-Altman analysis. **Results** In total, 305 CCI and 128 TDCI values were obtained: 305 paired PiCCI and PuCCI; 128 paired AutoCI-TDCI measurements. TDCI values ranged from 1.5 to 6.7 l/min.m² (mean 3.9 ± 1), AutoCI from 2.4 to 6.5 (3.8 ± 0.8), PiCCI from 1.5 to 7.1 (3.8 ± 1.2) and PuCCI from 2 to 7.6 (3.8 ± 1). Pearson correlation coefficient comparing all and mean PuCCI and PiCCI values had a R² of 0.77 and 0.86 respectively. Comparison between AutoCI and TDCI had a R² of 0.76. The above R² values were 0.73, 0.84 and 0.71 respectively when the Pulsioflex was connected to a radial line. Changes in AutoCI correlated well with changes in TDCI (R²=0.68) as did changes in PuCCI vs changes in PiCCI (R²=0.53). PPV obtained from Pulsioflex and PiCCO correlated better than SVV (R² of 0.86 vs 0.62). Changes in PiCCI and PuCCI induced by an intervention correlated well with each other (R²=0.94). Bland and Altman analysis comparing AutoCI with TDCI revealed a mean bias ± 2 SD (limits of agreement, LA) of 0.05 ± 0.94 l/min (with 27.3% error) while analysis of PuCCI vs PiCCI showed a bias (\pm LA) of 0.01 ± 1.12 l/min (29.1% error). **Conclusions** The preliminary results of an ongoing prospective study indicate that in unstable critically ill patients CI can be reliably monitored with PulsioFlex technology. Moreover the PulsioFlex was also able to keep track of changes in CI. Although TDCI remains a gold standard for the measurement of CI in ICU patients, PulsioFlex noncalibrated and less invasive monitoring (via a radial line) may provide useful information.

Reference

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Preliminary results of an ongoing prospective study on the use of noninvasive hemodynamic monitoring with Nexfin® for hemodynamic pattern recognition and outcome prediction in critically ill patients

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Introduction Non-invasive hemodynamic monitoring may become a new tool in the armamentarium of the intensive care unit. The few studies carried out so far have yielded conflicting results regarding the applicability and reliability of a continuous non-invasive analysis of finger blood pressure waveform using an inflatable finger cuff. There have been no studies investigating correlation of non-invasive finger arterial pressure monitoring with outcome in intensive care patients. We used the Nexfin® monitor (BMEYE, Amsterdam, The Netherlands), which is based on the volume-clamp principle of Penaz (1973) in combination with the physiological criteria of Wesseling (1995). The aim of the present study was to validate the Nexfin® in a mixed population of medical ICU patients

and to look for a pattern recognition that may be linked with outcome. **Methods** Prospective study in 40 patients admitted to the medical ICU (17 patients were mechanically ventilated, M/F ratio 1/1). Age 63.5 ± 16.7 , BMI 26.4 ± 5.4 , APACHE-II 20.8 ± 9.5 , SAPS-II 45.9 ± 18.9 , SOFA 7.2 ± 4.2 . A total of 18 patients were in shock, vasopressors were used in 11 and dobutamine in 7. For all patients, a simultaneous recording of arterial pressure by radial line (n=46), by PiCCO monitor (n=15) or by noninvasive BP measurement with arm cuff (n=17) was compared with non-invasive hemodynamic parameters obtained with the Nexfin monitor. If present, comparison of CO obtained with nexfin was compared with invasive hemodynamic monitoring devices (PiCCO n=15) and echocardiographic estimates of CO (n=11). Hemoglobin was measured via the Massimo technique (incorporated in the Nexfin® monitor) and via blood samples. Statistical analysis was performed with student's t test, Pearson correlation and Bland and Altman analysis with SPSS software. **Results** A total of 69 measurements in 40 patients were performed. In 3 patients measurement with Nexfin® was not possible. In total, 26 paired CO measurements were performed, CO was 6.4 ± 2.1 l/min (range 3.3--12). Pearson correlation coefficient comparing CO obtained with Nexfin® with the reference CO showed a good correlation ($R^2=0.5$). Bland and Altman analysis comparing both CO techniques revealed a mean bias \pm 2 SD (limits of agreement, LA) of 0.7 ± 3.9 l/min (58.3% error). The MAP was 84.6 ± 17.7 mmHg (57.5-131.5) and the values obtained with the Nexfin® correlated well with the reference method (PiCCO in 8 and radial line in 43) with an R^2 of 0.75. Bland and Altman analysis comparing both MAP techniques revealed a mean bias \pm 2 SD (LA) of 0.2 ± 19.7 mmHg (23.3% error). The MAP obtained with Nexfin® did not correlate well with noninvasive blood pressure ($R^2=0.1$). The hemoglobin (n=63) was 10.9 ± 1.6 g/dl (6.8—14.5) and the values obtained with the nexfin correlated poorly with the lab results ($R^2=0.1$). Bland and Altman analysis comparing both hgb techniques revealed a mean bias \pm 2 SD (LA) of 1.3 ± 4.6 (39.9% error). The 9 patients that died in the ICU had higher APACHE-II, ($p=0.07$) SAPS-II ($p=0.07$) and SOFA ($p=0.01$) scores and significantly lower MAP ($p=0.028$) and lower dp/dtmax ($p=0.029$), a marker for contractility. There were no outcome differences with regard to subgroup analysis in patients with either low or high CO or SVR. **Conclusions** The preliminary results of this ongoing prospective trial indicate that in unstable critically ill patients CO and MAP can be monitored noninvasively with the Nexfin®. The exact patient population for this technology has yet to be defined and more patients are probably needed for pattern recognition related to outcome, although the results indicate that a low MAP and dp/dtmax are related with poor outcome.

Validation of intrabladder and intragastric pressure measurements and correlation with intramucosal pH in a pig model of intra-abdominal hypertension

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Introduction Intra-abdominal pressure (IAP) is an important parameter and prognostic indicator of the patient's underlying physiologic status (1). The aim of this study is to validate continuous intragastric pressure (IGP) measurement via a balloon-tipped nasogastric tube with direct (IAP) and indirect intrabladder pressure (IBP) measurements and to look for a possible correlation between IAP and intramucosal gastric pH (pHi) in a pig model of intra-abdominal hypertension (IAH). **Methods** In 51 pigs, 611 paired IAP measurements were obtained. Five pigs served as control, in 5 pigs IAH was induced via intestinal occlusion while in the other 41 pigs the IAP was increased via pneumoperitoneum. The IAP was calculated at end-expiration using 2 different methods: the gold standard via an indwelling bladder catheter (IBP) zeroed at the level of the midaxillary line with the pigs in supine position, and via a balloon-tipped nasogastric tube (IGP) (Spiegelberg, Hamburg, Germany). The average number of measurements in each pig was 12. During the same period 86 simultaneous pHi and IGP measurements were performed in 40 pigs via another balloon-tipped nasogastric tube connected to the tonocap monitor (Datex, Helsinki, Finland). The abdominal perfusion pressure (APP) was defined as mean arterial pressure (MAP) minus IAP. Statistical analysis was done via Pearson correlation and Bland and Altman analysis, values are mean \pm SD unless stated otherwise. **Results** The mean IGP was 22.3 ± 12.7 mmHg (range 0-43.1), and IBP was 22.9 ± 12.6 mmHg (range 0-48). There was a very good correlation between IGP and IBP. For the whole set of paired measurements (n=611): $IBP=1.02 \times IGP$ ($R^2=0.96$, $p<0.0001$) and for the means per individual pig (n=51): $IBP=1.03 \times IGP$ ($R^2=0.96$, $p<0.0001$). The analysis according to Bland and Altman for the whole set of paired IAP measurements (n=611) showed a mean IAP of 22.6 ± 12.6 mmHg (range 0.1—44) with a bias ($\pm 1.96 \times SD$) of 0.6 ± 2.4 mmHg; the limits of agreement (LA) were -4.2 to 5.5 mmHg (with a % error of 21.5%). Looking at the mean values in each individual animal mean IAP was 22 ± 9.4 mmHg (range 2.5-37.9), with a bias of 0.8 ± 1.9 mmHg (LA -3 to 4.6) and a % error of 17.2%. These intervals are small and reflect a good agreement between the different IAP measurement methods. The mean pHi was 7.02 ± 0.28 (range 6.34—7.37) and correlated well with IGP ($R^2=0.7$, $p<0.001$). Analysis further showed that changes in IGP correlated well with changes in pHi

(R^2 0.66, $p < 0.001$). The MAP was 48.3 ± 14 mmHg (range 3–138) and APP was 24.9 ± 17.4 mmHg (range 0.2–92). During 388 paired measurements APP correlated significantly with pHi (in a logarithmic fashion, $R^2 = 0.18$), the correlation was linear and even better in conditions when APP was < 45 mmHg ($n = 334$): $pHi = 0.016 \times APP + 6.63$ ($R^2 = 0.55$, $p < 0.0001$). Further increased APP above 45 mmHg did not result in a further increase of pHi. **Conclusions** We found a very good correlation between IGP and IBP. Measurement via a balloon-tipped catheter placed in the stomach has major advantages over the standard intravesical method: continuous measurement of IAP as a trend over time is possible and there is no interference with estimation of urine output. Moreover APP is correlated with pHi while IAP and pHi are inversely correlated.

Reference

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Effect of intraabdominal pressure on respiratory function in patients undergoing ventral hernia repair

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Introduction The aim of the study was to determine the influence of intraabdominal pressure (IAP) on respiratory function after surgical repair of ventral hernia and to compare two different methods of IAP measurement during the perioperative period. **Methods** Thirty adult patients after elective repair of ventral hernia were enrolled into this prospective study. IAP monitoring was performed via both a balloon-tipped nasogastric probe (IGP, CiMON, Pulsion Medical Systems, Munich, Germany) and a urinary catheter (IBP, UnoMeterAbdo-Pressure Kit, UnoMedical, Denmark) on five consecutive stages: 1) after tracheal intubation (AI), 2) after ventral hernia repair, 3) at the end of surgery, 4) during spontaneous breathing trial through the endotracheal tube, 5) at one hour after tracheal extubation. The patients were in the complete supine position during all study stages. **Results** The IAP (measured via both techniques) increased on average with 12% during surgery compared to AI ($p < 0.02$) and with 43% during spontaneous breathing through the endotracheal tube ($p < 0.01$). In parallel, the gradient between $PaCO_2$ and $EtCO_2$ ($P(a-et)CO_2$) rose significantly, reaching a maximum during the spontaneous breathing trial. The PaO_2/FiO_2 decreased by 30% one hour after tracheal extubation ($p = 0.02$). The dynamic compliance of respiratory system reduced intraoperatively by 15–20% ($p < 0.025$). At all stages, we observed a significant correlation between IGP and IBP ($\rho = 0.65–0.81$, $p < 0.01$) with a mean bias varying from -0.19 mm Hg (2SD 7.25 mm Hg) to -1.06 mm Hg (2SD 8.04 mm Hg) depending on the study stage. Taking all paired measurements together ($n = 133$), the median IGP was 8.0 (5.8–13.1) mmHg and median IBP was 8.8 (5.5–11.0) mmHg. Bland and Altman analysis showed an overall bias of -0.67 mm Hg (2SD 7.16 mm Hg) with percentage error of 14.4%. **Conclusions** The increase of $P(a-et)CO_2$ and decrease of PaO_2/FiO_2 ratio reflects the changes in respiratory function such as atelectasis formation due to increased IAP. Estimation of IAP via IGP or IBP demonstrated a significant correlation between both methods, although the limits of agreement were quite large suggesting that the abdomen may not behave always like a fluid filled compartment.

Systematic review and meta-analysis on the impact of a positive cumulative fluid balance on intraabdominal hypertension and outcome in critically ill patients.

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Introduction A positive daily and cumulative fluid balance has been associated with intra-abdominal hypertension (IAH) and worse outcomes in adult critically ill patients. **Methods** We conducted a systematic review of published and unpublished studies. We searched MEDLINE, PubMed, EMBASE, Scopus, Web of Science, The Cochrane Database, Ovid, clinical trials registries and bibliographies of included articles. Two authors independently abstracted the data on study design, methodological quality, patient characteristics and outcome.

Results Among all identified citations, 1 meta-analysis (albeit only published in abstract form), 10 randomized controlled clinical trials (of which 4 were blinded), 7 interventional studies, 28 observational studies, and 4 case series met the inclusion criteria. All together, a total of 23625 critically ill patients were studied and in 23 studies the intra-abdominal pressure (IAP) was also measured. The cumulative fluid balance after 1 week of ICU stay was more positive in nonsurvivors with 4.5L (95%CI 2.9-6.1, $p < 0.0001$). Interventions aimed to obtain a restrictive fluid management resulted in a less positive cumulative fluid balance after 1 week of ICU stay with 5.3L (95%CI 2.8—7.8, $p < 0.0001$). Restrictive fluid management resulted in a decreased mortality of 22.2% (compared to 29.1% in patients treated with liberal fluid management), with an accompanying OR of 0.38 (95%CI 0.28—0.53, $p < 0.0001$). Patients with IAH had a more positive cumulative FB after 1 week of ICU stay with 2.9L (95%CI 1.8—4, $p < 0.0001$). Interventions to decrease fluid balance resulted in a decrease in IAP: an average total fluid removal of 6.8L resulted in a drop in IAP from 21.5 mmHg (range 8—38) to 12 mmHg (range 5—18). **Conclusions** A positive cumulative FB is associated with worse outcomes. Interventions to limit a positive cumulative FB are associated with improved outcomes. A positive cumulative FB is associated with IAH.

