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Pulse-induced Continuous Cardiac Output Monitor versus Trans-esophageal Doppler Monitor for Optimization of Fluid Management in Patients Undergoing Major Abdominal Surgery. A Comparative Study

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Authors' contributions

This work was carried out in collaboration between all authors. Author HFH contributed to the study design, pilot results, calculated sample size, anesthetized and followed up patients, helped in collecting data and revised the medical charts. Author MZA contributed to the study design, pilot results, calculated sample size, supervised anaesthesia and follow-up of patients, helped perform the statistical analysis and drafted the manuscript. Authors AIR and MMA contributed to the study design and revised the manuscript. Author ASEH helped collect data, revise the medical charts, perform the statistical analysis, and draft the manuscript. Author NGES helped collecting data, revised the medical charts, and drafted the manuscript. Author RSE helped collecting data and revised the medical charts. All authors read and approved the final manuscript.

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ABSTRACT

Background: Perioperative fluid management is essential to the practice of anaesthesia. Outcomes may be improved if fluid therapy is individualized according to the patient's fluid responsiveness. Pulse-induced continuous cardiac output (PiCCO) monitor is an invasive device that quantifies several parameters, including cardiac output (CO), stroke volume variation (SVV) and extravascular lung water (EVLW). Trans-oesophageal Doppler monitoring (TED) is another minimally invasive form and has the benefit of providing beat to beat analysis.

Aim of Work: We designed this prospective, randomized comparative study to evaluate the use of PiCCO monitor from the fluid and haemodynamic point of view in comparison to TED monitor in order to maintain an adequate circulatory volume ensuring end-organ perfusion and oxygen delivery.

Patients and Methods: This study was performed on 72 patients of either sex (ASA I-II), undergoing major abdominal surgery. Patients were randomly allocated into two groups; **PiCCO group (*n*=36);** where fluid management was guided by SVV & colloid boluses were given to maintain SVV below 10% and **TED group (*n*=36);** where fluid management was guided by (systolic flow time corrected for heart rate) (FT_c) & colloid was infused when the (FT_c) < 0.35 second, the fluid challenge would be repeated until FT_c raised > 0.40 second with no change in SV. Laboratory parameters of organ hypoperfusion in perioperative period were recorded as well as the number of postoperative complications, mortality and length of ICU stay.

Results: PiCCO group received more intraoperative colloids (*P*=0.001) and had lower incidence of hypotensive events (*P*=0.001). Postoperative lactate levels were lower in PiCCO group (*P*=0.04). PiCCO group showed fewer numbers of patients developed complications & overall number of postoperative complications (*P*=0.01). It also showed shorter duration of ICU length of stay (*P*=0.01). No mortality was recorded in both groups.

Conclusions: During major abdominal surgery; intraoperative fluid optimization using PiCCO monitor showed more haemodynamic stability and was associated with a lower incidence of postoperative complications, organ dysfunction and infectious complications with a tendency to decrease the ICU length of stay in comparison to TED monitor.

Keywords: Goal directed fluid therapy; PiCCO monitor; TED monitor.

ABBREVIATIONS

ABG : Arterial blood gases analysis
ARF : Acute renal failure
CFI : Cardiac function index
CO : Cardiac output
CVP : Central venous pressure
EVLW : Extravascular lung water
FFP : Fresh frozen plasma
FTc : Systolic flow time corrected for heart rate
GEDV : Global end-diastolic volume
HCO_3^- : Bicarbonate
HR : Heart rate
ITBV : Intrathoracic blood volume
MAP : Mean arterial pressure
PAC : Pulmonary artery catheters
PiCCO : Pulse-induced continuous cardiac output
PPV : Pulse pressure variation
$S_{CV}O_2$: Central venous oxygen saturation
SV : Stroke volume variation
SVR : Systemic vascular resistance
SVV : Stroke volume variation
TED : Trans- oesophageal Doppler monitoring

1. INTRODUCTION

Perioperative fluid management is essential to the practice of anaesthesia, especially for major surgeries with obvious stress response, altered capillary permeability, and excessive fluid shifts [1].

Cardiopulmonary, gastrointestinal, and renal functions, wound healing, and coagulation may all be influenced by perioperative fluid administration [2]. The aim of intraoperative fluid therapy is to maintain an adequate circulatory volume to guarantee end-organ perfusion and oxygen delivery [3]. Both hypo- and hypervolaemia are known to increase perioperative morbidities and mortality; therefore, assessment of the patients' actual haemodynamic status can guide appropriate therapy [4].

Outcomes may be improved if fluid therapy is individualized according to the patient's individual fluid responsiveness. This is derived from the old physiological principle of the Frank–Starling

curve and known as individualized goal directed therapy 'GDT' [5].

Traditional measurements do not have the ability to adequately identify and guide fluid therapy. Neither the central venous pressure (CVP) figure nor the rate of its change is accurate in assessing the circulatory volume or in predicting the response to a fluid challenge. Therefore, caution should be taken in interpreting CVP data to guide fluid administration [6].

Unfortunately, it became clear that the use of pulmonary artery catheters (PAC) can cause increased morbidity and mortality, which destabilized interest in the idea of using physiological targets to optimize cardiovascular performance and improve outcomes [7].

Minimally invasive monitors include trans-oesophageal Doppler monitoring (TED) and arterial pulse waveform analysis (stroke volume variation (SVV), pulse pressure variation (PPV)) [8]. Trans-oesophageal Doppler monitoring (TED) is a minimally invasive form for cardiac output monitoring and has the benefit of providing beat to beat analysis. It is a thin plastic tube placed in the oesophagus parallel to the descending aorta and emits ultrasound waves directed towards the flow of blood. Cardiac output is calculated from the amount of blood that moves past the probe over a given time (stroke distance) and estimates the cross-sectional area of the aorta determined from normograms [9].

Other methods are invasive and require insertion of both arterial and central venous accesses to measure cardiac output as the PiCCO systems which use pulse contour analysis to measure the stroke volume [8]. PiCCO quantifies several parameters, including continuous cardiac output (CO), cardiac preload, systemic vascular resistance (SVR), Global end-diastolic volume (GEDV), stroke volume variation (SVV) and extravascular lung water (EVLW). It requires a central venous line ideally sited in the internal jugular or subclavian vein, and an arterial catheter with a thermistor placed in one of the larger systemic arteries, e.g. the femoral artery [10].

Thus, optimization of intravascular volume during major abdominal surgery and avoiding hypo- or hypervolaemia using different cardiac output monitoring devices is associated with better intraoperative haemodynamic stability and significantly lower incidence of complications [11].

We designed this prospective, randomized comparative study to evaluate the use of PiCCO system from the fluid and haemodynamic point of view in comparison to the TED in order to maintain an adequate circulatory volume ensuring end-organ perfusion and oxygen delivery to tissues. The primary outcome will be the postoperative morbidity based on number of infectious and other organ complications. Secondary outcome parameters will be the evaluation of both CO monitoring devices from many aspects to detect which is more accurate, easier to use, hospital/ ICU length of stay and all-cause mortality.

2. MATERIALS AND METHODS

This prospective, double-blind randomized comparative study was conducted in the Anaesthesia and Surgical Intensive Care Department, at Theodor Bilharz Research Institute on seventy two adult patients of either sex (ASA physical status I-II), above 18 years old, undergoing major abdominal surgery with expected duration more than 120 minutes and blood loss more than 1000 ml (e.g. radical cystectomy, radical prostatectomy, gastrectomy, pancreatectomy, spleenectomy). Patients suffering from oesophageal pathology, uncontrolled diabetes mellitus or hypertension, irregular heart rhythm, advanced cardiac condition, severe metabolic, neurological, endocrinal, hepatic or renal impairment, metastatic malignancies, contraindications to femoral arterial line insertion; stent, bypass or severe peripheral arterial occlusive disease, body weight less than 55 kg or more than 140 kg, pregnant women, laparoscopic surgical plan and patients' refusal to participate were excluded.

2.1 Sample Size Calculation

Based on pilot study, sample size was calculated according to the difference in the mean value of hypotensive events between PiCCO (1.52 ± 0.43) and TED (3.12 ± 0.92) groups measured intra-operatively, with an effect size of 0.67. Assuming α=0.05, power of 80%, so a sample size of 36 patients per group would be required. *(GPower 30; http:www.psycho.uni-duesseldorf.de).*

Patients were double-blindly randomly allocated into one of two equal groups of thirty six patients each using simple (sealed envelope) technique

done by a senior anaesthesia resident; either PiCCO-guided intraoperative fluid management (Group PiCCO) or trans-oesophageal Doppler-guided intraoperative fluid management (Group TED).

In the induction room, intravenous access was established and an intravenous infusion of Ringer's acetate solution was started. Standard continuous monitoring including five-lead ECG, non-invasive blood pressure (NIBP), and pulse oximetry (S_pO_2), end-tidal carbon dioxide ($P_{ET}CO_2$) and anaesthesia gas analyzer (Dräger infinity Kappa, Dräger Medical Corporation, Germany) were attached to all patient. Neuromuscular monitoring using TOF-Guard (INMT Organon Teknika NV-Belgium) was also used.

Data were documented at 5-min intervals. BIS was derived from the frontal electroencephalogram using BIS sensor electrodes.

Premedication was given in the form of intravenous midazolam (0.05 $mg.kg^{-1}$). 100% Oxygen supplementation (5 $l.min^{-1}$) via a face mask was applied for 5 minutes before intubation. Patients were then be double-blindly randomized into two groups; **(Group TED) or (Group PiCCO)**.

Anaesthesia was then induced using I.V. fentanyl 2 $\mu g.kg^{-1}$ and I.V. propofol (2 $\mu g.kg^{-1}$) until loss of consciousness. Face mask ventilation was then established using oxygen/air mixture (F_iO_2=0.5), for 3 minutes by using IV atracurium as a muscle relaxant in an intubating dose of 0.5 $mg.kg^{-1}$ until adequate relaxation is established. Endotracheal intubation was done and IPPV using a closed circuit was established using isoflurane in a mixture of oxygen/air (F_iO_2=0.5) providing end-tidal carbon dioxide tension ($P_{ET}CO_2$) 35-40 mmHg. The dial-up isoflurane percentage will be adjusted to establish a BIS value of 40-50.

Neuromuscular blockade was achieved with intermittent bolus doses of atracurium (0.1 $mg.kg^{-1}$) when Train of Four (TOF) ratio reached 25%. Reversal of neuromuscular blockade will be achieved by intravenous administration of neostigmine 0.05 $mg.kg^{-1}$ and atropine 0.02 $mg.kg^{-1}$.

In PiCCO group**;** after general anaesthesia had been established, placement of a central venous line (internal jugular vein) and a femoral arterial line were done. The PiCCO system (Pulsion medical system, Dräger infinity kappa XLT) was calibrated according to the instructions of the manufacturer by transpulmonary thermodilution (TP-TD) with 20 ml cold saline (4℃) and pulse contour measurements were started. To improve the quality of our reference data, the PiCCO system was recalibrated every 15 min.

In TED group**:** The oesophageal Doppler probe (CardioQ, Deltex Medical, Chichester, UK) was inserted orally after tracheal intubation and positioned approximately 35–40 cm from the teeth to achieve an optimal position to the descending thoracic aorta.

TED measures the velocity of blood flow in the descending thoracic aorta. Integrating the velocity–time curve gives the distance traveled by the blood following cardiac systole and multiplying this by the cross-sectional area (estimated by a nomogram) derives stroke volume and cardiac output.

In both groups**,** intraoperative fluid management was in the form of maintenance, deficit and third space loss replacement. Maintenance was calculated as 4 $ml.kg^{-1}.h^{-1}$ IV acetated Ringer's solution for the first 10 kg body weight, 2 $ml.kg^{-1}h^{-1}$ for the second 10 kg body weight, and then 1 $ml.kg.^{-1}h^{-1}$ IV administration of the same solution for the rest of body weight over 20 kg. Deficit was calculated as the maintenance multiplied by fasting hours and was given as acetated Ringer's, half of it in the first hour of the operation and the rest in the following 2 hours divided equally. Third space loss was managed using 6-10 $ml.kg.^{-1}h^{-1}$ as acetated Ringer's. Packed RBCs were transfused based on hemoglobin level (less than 7-8 $g.dl^{-1}$). Transfusion of platelets were done if platelet count < 50.000 /dl and fresh-frozen plasma if INR > 1.5.

In addition to the previous fluid management, IV boluses of 200 cc of Hydroxy-Ethyl Starch (HES 130/ 0.4) were given guided by PiCCO or TED to a maximum volume of 50 $ml.kg^{-1}.day^{-1}$ as follows:

In PiCCO group**:** whenever intraoperative SVV increases >10, we gave 200 ml of HES130/0.4 as a bolus over 5 minutes to establish a SVV ≤10, and continued giving the same colloid keeping SVV≤10 and no increase in stoke volume (SV) more than 10%.

In TED group**:** HES Colloid was infused when the (systolic flow time corrected for

heart rate) (FT_c) < 0.35 second. If the stroke volume was maintained or increased by the fluid challenge and the FTc remained below 0.35 second, the fluid challenge would be repeated. If the stroke volume raised >10% but the FT_c > 0.35 second, the fluid challenge would be repeated until no further rise in SV occurred. If the FT_c raised > 0.40 second with no change in stroke volume, indicating that intravascular volume is optimized, further fluid would not then be administered until the FT_c or SV fell by 10%.

Patients demography; age, sex & ASA physical status, haemodynamic monitoring; heart rate (HR) & mean arterial pressure (MAP), central venous pressure (CVP), Arterial blood gases analysis (ABG), central venous oxygen saturation $S_{CV}O_2$, serum lactate, urine output, core temperature, blood loss, intravenous fluid administration, volume of packed RBCs transfused, total units of platelets and FFP transfused were all recorded throughout the procedure. We recorded two readings of these variables; one after induction of anaesthesia and before skin incision and another at the end of surgery. Any decline in HR or MAP ≥ 20% of the preoperative values was treated with IV atropine or ephedrine respectively. Number of hypotensive events was also recorded.

Postoperative laboratory data including arterial PH, serum HCO_3^-, Central venous oxygen saturation $S_{CV}O_2$ and Serum lactate level were continued to be recorded for 8 and 24 hours after the end of surgery. Until discharge, patients were continued to be monitored for infectious and organ complications (cardiac, pulmonary, gastrointestinal, renal and thrombotic). Total number of complications and the number of patients with complications were calculated for each group. The ICU and standard care length of stay and length of ventilator support were recorded. Number of mortality for each group were calculated.

2.2 Statistical Analysis

Data were analyzed using Microsoft Excel 2010 and statistical package SPSS version 21.0 for windows (SPSS IBM., Chicago, IL). PICCO and TED were expressed as mean ± SD with 95% confidence interval with medians for quantitative variables, and using the frequencies and percentage for qualitative ones; *P*-value < 0.05 is considered statistically significant*; P*-value <0.01 is considered statistically highly significant. Diagnostic parameters of subjects will be compared using the non-parametric Wilcoxon-Mann-Whitney U-test, Independent-sample (t) test and paired-samples (t) test while Chi-square (χ^2) test will be used for comparison of categorical data. Whenever the expected values in one or more of the cells in a 2x2 tables was less than 5, Fisher exact test will be used instead and using linear by linear association in larger than 2x2 cross-tables.

3. RESULTS AND DISCUSSION

3.1 Results

From November 2013 through July 2015, 133 patients were enrolled in this study and then assessed for inclusion legibility; 61 patients were excluded from the study; 49 didn't fulfill the study's inclusion criteria and 12 patients refused to participate in this trial as shown in Fig. 1.

The two studied groups were comparable regarding age, gender and ASA physical status (Table 1).

Table 1. Demographic features of the two studied groups

	PiCCO *(n=36)*	**TED *(n=36)***	***P*-value**
Age (yrs)	63.39±4.57	63.3±5.13	0.4
Sex (F/M)	18/18 (50/50%)	17/19 (47.2/52.8%)	0.5
ASA (I/II)	27/9 (75/25%)	29/7 (80.6/19.4%)	0.3

Data were expressed as mean ±SD or number (%)
ASA= American Society of Anesthesiologists

All haemodynamic variables were comparable between the two groups at the beginning and at the end of surgery except for the CVP in which there was statistical significant difference between PiCCO and TED group at the beginning of surgery *(P=0.04*).

In PiCCO group, a statistical significant decrease in the heart rate (74.08±8.23 vs. 70.17±7.35; *P*=0.04), and also a high statistical significant increase in CVP (8.03±1.73 vs. 10.08±2.19; *P*=0.001) were observed at the end of surgery compared to baseline records with no such statistical difference found in the TED group regarding the HR & CVP readings. In both groups there were high statistical significant decreases in MAP at the end of surgery compared to the baseline values (*P*=0.001) (Table 2).

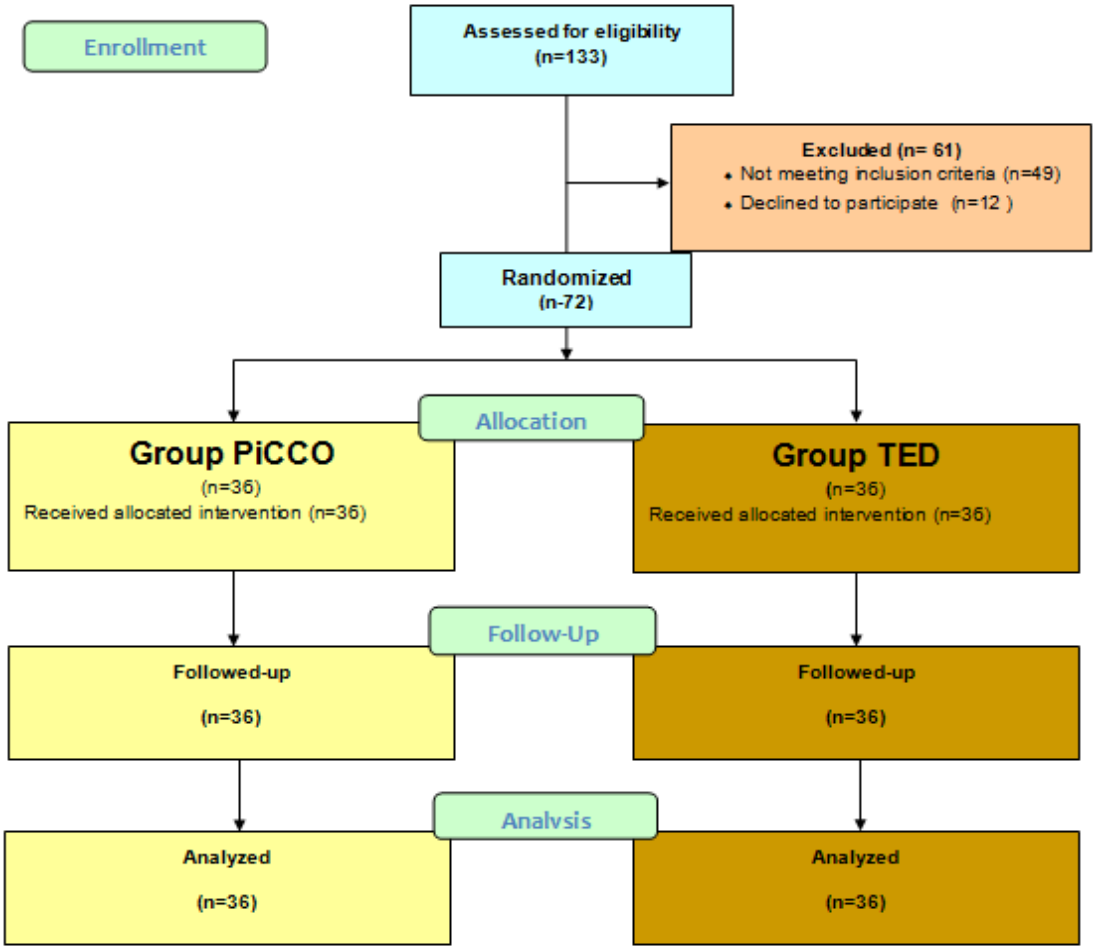

Fig. 1. The course of patients through this study

Table 2. Haemodynamic variables in the two studied groups

	PiCCO ***(n=36)***	**TED** ***(n=36)***	***P*-value**
Baseline			
HR (beat/min)	74.08±8.23	74.11±6.48	0.09
MAP (mmHg)	103.14±7.78	103.33±9.49	0.1
CVP (mmHg)	8.03±1.73	9.06±2.41	0.04*
End of surgery			
HR (beat/min)	70.17±7.35* *(P= 0.04 vs. baseline)*	73.39±9.39	0.06
MAP (mmHg)	92.39±7.89** *(P= 0.001 vs. baseline)*	91.19±9.19** *(P= 0.001 vs. baseline)*	0.3
CVP (mmHg)	10.08±2.19** *(P= 0.001 vs. baseline)*	10.00±2.00	0.3

*Data were expressed as mean ±SD. *P< 0.05= Significant; **P<0.01= Highly significant.*
HR= Heart rate, MAP= Mean arterial pressure, CVP= Central venous pressure

Blood loss volume was statistically significant higher in PiCCO group (1452.8±443.68 ml) compared to TED group (900±352.95 ml) (*P*=0.001). The blood transfusion volume was statistically significant higher in PiCCO group (1326±468 ml) than TED group (638±238 ml) (*P*=0.001). PiCCO group patients received a statistically significant larger amount of colloid infusions (1390.3±182.37) compared to TED (883.33±221.04) (*P*=0.001). There was no statistically significant difference between the two study groups regarding the volume of crystalloids infused to all patients. Fourteen patients required plasma transfusion in the PiCCO group in comparison to only five patients in the TED group with statistical significance (*P*=0.01) (Table 3).

Table 4 shows intraoperative events; a high statistically significant lower incidence of intraoperative hypotensive events in PiCCO group (1.61±0.49) compared to (3.39±1.1) in TED group (*P*=0.001). Regarding the need of intravenous norepinephrine usage, 5 patients (13.0%) in PiCCO group and 13 patients (36.1%) in TED group received the drug with statistical significance (*P*=0.03). The urine output was significantly higher in PiCCO group (2097± 476.58 ml) compared to TED group (1538±347.46 ml) (*P*=0.001).

Both groups were comparable regarding PH readings (Fig. 2) at the beginning and at postoperative follow-up periods. Arterial pH was significantly lower at the end of operation in both groups compared to the baseline readings (*P*=0.01) and then turned to normal values during the postoperative period.

There was a statistically significant difference between the two study groups in serum HCO_3^- levels (Fig. 3) at the beginning and at the end of surgery (*P*=0.01). At the end of surgery, both groups showed significant decrease in the serum bicarbonate levels compared to the baseline readings was (PiCCO; *P*=0.001, TED; *P*=0.002). In the TED group, there was significant increase in serum HCO_3^- level 8 hrs and 24 hrs postoperatively in comparison to the baseline readings (*P*=0.001), while in the PiCCO group the increase in HCO_3^- occurred only 24 hrs postoperatively (*P*=0.001).

No statistical difference between the two study groups was observed regarding $S_{cv}O_2$ readings (Fig. 4). In both groups, there was significantly higher $S_{cv}O_2$ values at the end of surgery and 24hours postoperatively (*P*=0.001) in comparison to the baseline readings. 8 hours postoperatively, statistically significant lower values of $S_{cv}O_2$ were observed in both groups (PiCCO; *P*=0.005, TED; *P*=0.02) compared to the baseline readings.

There was statistical significant difference between both groups in serum lactate levels (Fig. 5) at the end (*P*=0.01), 8 hrs (*P*=0.02) and 24 hrs postoperatively (*P*=0.04). A statistically

Table 3. Intraoperative blood loss volume, blood transfusion, crystalloids infused, & plasma transfusion in the two study groups

	PiCCO ***(n=36)***	**TED** ***(n=36)***	***P*-value**
Blood loss (ml)	1452.8±443.68	900±352.95	0.001**
Blood transfusion (ml)	1326±468	638±238	0.001**
Colloid transfusion (ml)	1390.3±182.37	883.33±221.04	0.001**
Crystalloid transfusion (ml)	3150±758.3	3052±392.4	0.4
FFP transfusion (units n)	14 (38.9%)	5 (13.9)	0.01*

*Data were expressed as mean ±SD or number (%).*P< 0.05= Significant; **P<0.01= Highly significant. FFP= Fresh frozen plasma*

Table 4. Intraoperative events hypotensive events, the need of intravenous norepinephrine & urine output in the two study groups

	PiCCO ***(n=36)***	**TED** ***(n=36)***	***P*-value**
Hypotensive events (n)	1.61±0.49	3.39±1.1	0.001**
I.V.Noradrenaline (n)	5 (13%)	13 (36.1%)	0.03*
Urine output (ml)	2097±476.58	1538±347.46	0.001**

*Data were expressed as mean ±SD or number (%).*P< 0.05= Significant; **P<0.01= Highly significant*

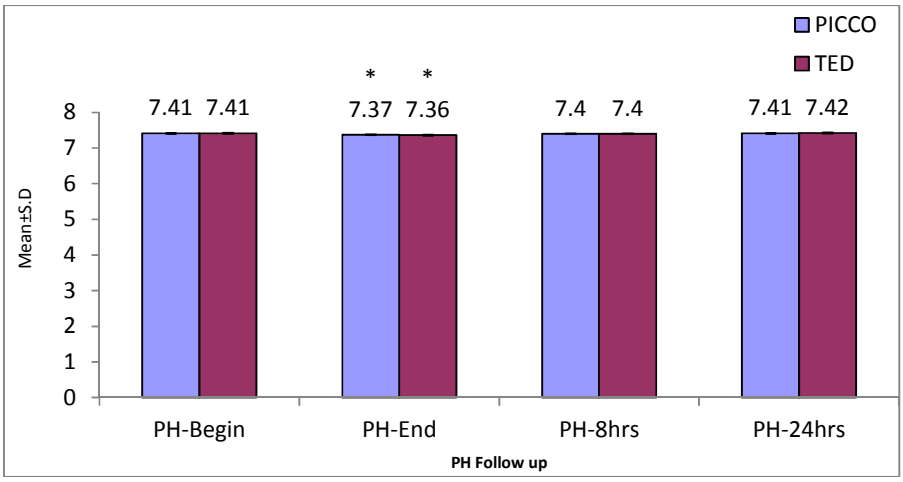

Fig. 2. Mean value of PH for cases in the study groups at beginning and on follow up data were expressed as mean ± SD

**P=0.01= Significant in comparison to PH- Begin*

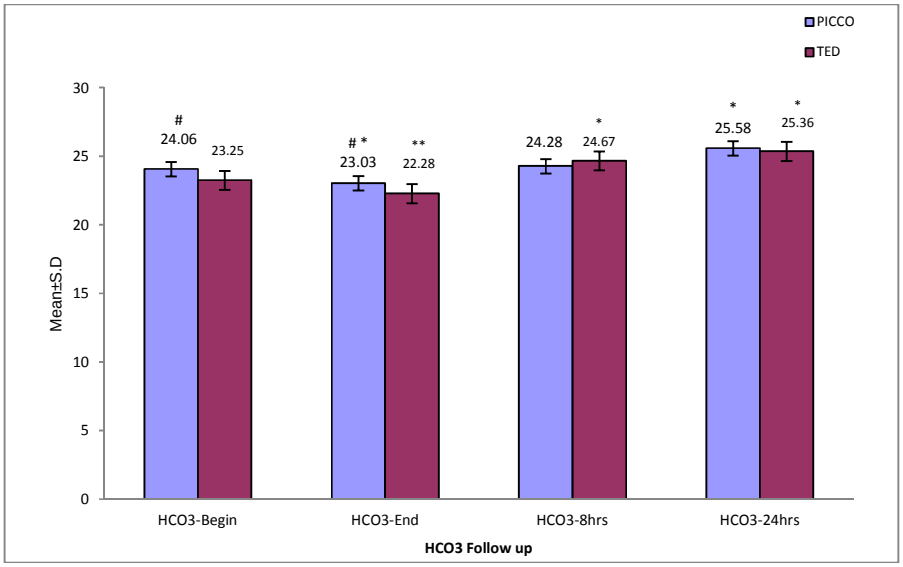

Fig. 3. Mean value of HCO_3^- for cases in the study groups at beginning & on follow up data were expressed as mean ± SD

#P=0.01= Significant between the two groups at the same time

**P=0.001= Highly significant in comparison to HCO_3^--Begin.*

***P=0.002= Highly significant in comparison to HCO_3^-Begin*

significant increase in serum lactate concentration was observed in both groups at the end of surgery and 8 hrs postoperatively (*P*=0.001). Only in the PiCCO group a significant decrease in serum lactate level 24 hours after operation (*P*=0.02) compared to the baseline concentrations.

Regarding postoperative outcome (Table 5), there was no mortality recorded in both groups. A statistically significant difference was observed in the ICU length of stay which was shorter in the PiCCO group (3 days) in comparison to TED group (7 days) (*P*=0.01). Number of patients with organ dysfunction and infectious complications in the postoperative period was significantly lower in the PiCCO group (4 patients) compared to 9 patients in the TED group (*P*=0.01). Number of postoperative complications was significantly lower in the

PiCCO (4 complications) in the form of pneumonia, wound infection, arrhythmias and UTI compared to 9 complications in the TED group in the form of pneumonia, sepsis, need for mechanical ventilation, decubitus infection, ARF and wound infection (*P*=0.01).

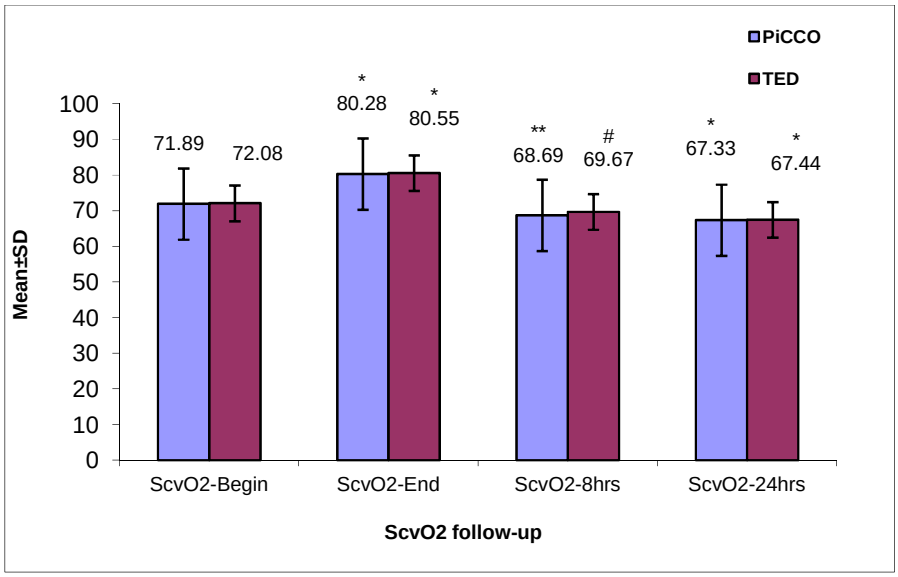

Fig. 4. Mean value of $S_{cv}O_2$ for cases in the study groups at beginning & on follow up data were expressed as mean ± SD

**P=0.001= Highly significant in comparison to $S_{cv}O_2$-Begin.*
***P=0.005= Highly significant in comparison to $S_{cv}O_2$ Begin*
#P=0.02= Significant in comparison to $S_{cv}O_2$ Begin

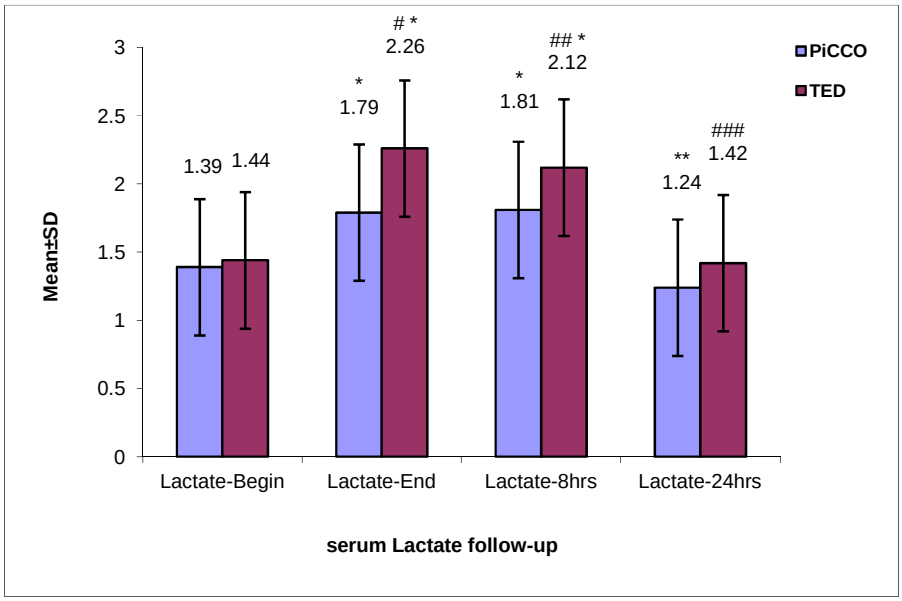

Fig. 5. Mean value of serum Lactate in the study groups at beginning & on follow up data were expressed as mean ± SD

**P=0.001= Highly significant in comparison to lactate-Begin.*
***P=0.02= Significant in comparison to lactate-Begin*
#P=0.01= Significant between the two groups at the same time
##P=0.02= Significant between the two groups at the same time
###P=0.04= Significant between the two groups at the same time

Table 5. Postoperative outcome and complications

	PiCCO *(n=36)*	TED *(n=36)*	*P*-value
Mortality (n)	0	0	N.A
ICU stay (day)	3	7	0.01*
Patients with complications (n)	4	9	0.01*
Total complications (n)	4	9	0.01*

Data were expressed as numbers
**P< 0.05= Significant*

3.2 Discussion

Fluid therapy is an art in the practice of intraoperative anaesthesia, as it has an important impact on longer-term postoperative outcomes [12]. The PAC has been considered to be the "gold standard" for CO monitoring and fluid management. The invasiveness and high rate of complications associated with this device renders it as unsuitable for routine use in most cases [13].

Over the past few years, the use of less invasive methods for haemodynamic monitoring has gained popularity. Minimally invasive monitors for intraoperative GDT include many devices e.g. TED monitoring and PiCCO monitoring [13].

The aim and novelty of this study was to compare two minimally invasive CO monitoring (PiCCO monitor *vs.* TED monitor) used for intraoperative fluid optimization in surgical patients undergoing major abdominal surgery regarding intraoperative optimization of haemodynamics and cellular function status, postoperative outcome; morbidity, length of ICU stay and mortality.

In this study, intraoperative fluid optimization in patients undergoing major abdominal surgery using PiCCO monitor revealed more haemodynamic stability during operation, and was associated with a lower rate of postoperative complications, lower number of patients with organ dysfunction and infectious complications in the postoperative period with a tendency to decrease ICU length of stay in comparison to TED monitor with no difference in mortality between the two groups.

The results of this study agree with, Goepfert and his coworkers [14] who compared the effect of intraoperative fluid management in 100 patients undergoing elective cardiac surgery guided by the PiCCO monitoring versus CVP; they found that PiCCO-based fluid management was associated with significant fewer postoperative complications. They also found that the PiCCO group has lesser time to achieve ICU discharge criteria, lesser number of days on vasopressors and shorter length of stay in ICU. They also agree with us as they found that patients in the PiCCO group received significantly more colloid solutions than in the control group (P<0.001), but with no significant difference in the total amount of crystalloids during CABG. Unlikely, they found that the urine output did not differ between both groups during surgery. They also found that serum lactate levels were lower in the PiCCO group 12 h, 24 h and 36 h than CVP group.

Lenkin et al. [15] compared the effects of GDT either PAC or by PiCCO monitor in 40 patients undergoing elective cardiac valve surgery, the PiCCO group showed results similar to results of the present study in the form of significant increase in the volume of fluid therapy, improvement of haemodynamics and oxygen delivery and lesser duration of postoperative respiratory support. However, the duration of the ICU stay and hospitalization did not differ between the two study groups. They also found that the incidence of colloid administration and the postoperative fluid balance tended to be higher in the PiCCO group. The total volume of postoperative fluid therapy in the PiCCO group exceeded that of the PAC group by 20% (P= 0.01) which agree with the results of the present study.

Kraft et al. [16] studied the fluid resuscitation guided by PiCCO monitoring in comparison to the CVP method in 152 paediatric patients with severe burns. The study showed that adjusted fluid management using the PiCCO system in burned paediatric patients has beneficial effects on the hospital course, patient outcomes and lower sepsis rate. They also showed a significant lower incidence of cardiac and renal failure. There was statistically insignificant difference between both study groups in terms of mortality, which is comparable with the present study results. They also agree with our results in finding that CVP values of PiCCO-monitored patients were significantly higher (P<0.05). They also showed a decrease in the HR compared to baseline. Contrary to our results Kraft et al. [16] recorded a significantly lower input of crystalloid and colloid resuscitation solutions in the PiCCO group compared to CVP group in burned

paediatric patient. This may be due to the difference in patient's inclusion criteria.

Data from Trof and his coworkers' study [17] stated that haemodynamic management guided by PiCCO monitoring versus PAC in patients with septic shock did not affect ventilator-free days, lengths of ICU stay, organ failures, and mortality of critically ill patients. Use of the PiCCO monitoring resulted in more days on mechanical ventilation and ICU length of stay compared with the PAC algorithm. This may be due to the use of the gold standard most invasive method (PAC) which gives the best results and hence the best managent.

Another study by Zhang et al. [18] who included a total of 708 patients with ARDS and septic shock, found that PiCCO-based fluid management did not improve outcome when compared to CVP-based fluid management. Treatment guided by PiCCO monitoring resulted in more negative fluid balance than the CVP group. This result could be explained that patients with septic shock and/ or ARDS usually have compromised pulmonary and circulatory function unlike cardiac surgery patients.

A retrospective study was carried out by Sun et al. [19] where clinical data of 18 patients with severe acute pancreatitis, who had undergone fluid resuscitation under the guidance of PiCCO were analyzed in comparison to clinical data of 25 cases who had undergone fluid resuscitation without the guidance of PiCCO. Meeting our results, the study showed that the PiCCO group received more volume of fluid than the control group.

Also in a multicentre, multinational epidemiological study [20] in a cohort of 331 critically ill patients who haemodynamically monitored using PAC or PiCCO in eight ICUs in four countries. On direct comparison, they found that the use of PiCCO was associated with a greater positive fluid balance and fewer ventilator- free days. They concluded that positive fluid balance was a significant predictor of outcome.

Another study by Mutoh et al. [21] used postoperative PiCCO monitor to guide fluid management in patients with subarachnoid hemorrhage who underwent surgical clipping compared to the PAC, it showed that the PiCCO monitor group experienced lesser frequencies of vasospasm and cardiopulmonary complications compared to those managed with standard therapy (P<0.05), but unlike our results they required less fluid administration compared to the PAC group to attain the haemodynamic target.

Lu et al. [22] studied the effect of GDT guided by PiCCO measurements on 82 septic shock patients randomly divided into PiCCO group and conventional group. Meeting the results of the present study, they found that lactate clearance rate in PiCCO group was significantly higher than that of control group. Also, duration of mechanical ventilation (P=0.001) and ICU stay (P=0.004) were significantly reduced in PiCCO group compared to control group. The hospital mortality was slightly lower in PiCCO group.

In a case-report where the PiCCO monitor was used by Brogly et al. [23] to optimize haemodynamic condition and to guide fluid therapy in a 28-year-old woman with a severe cardiomyopathy who was submitted to an emergency caesarean section under general anaesthesia. The left ventricle's ability to handle with an increase in preload was indicated by the SVV, estimation of lung water is important to assure that administered fluids are not increasing cardiac congestion, provoking consequently pulmonary edema. After 48 h, the patient had maintained a stable haemodynamic state with no need for further fluid loads or vasoactive support, she was discharged from the hospital, with no post-operative complication.

On the other hand, numerous studies [24,25] have compared perioperative Doppler-guided intravascular volume replacement strategies with conventional clinical volume replacement in various groups of surgical patients, including abdominal, cardiac, orthopedic, urologic, and gynecologic surgery and multiple-trauma patients. The investigators used different experimental protocols, with the common basis that in the TED groups fluid boluses were administered according to an algorithm, until a defined haemodynamic target was reached. All of these studies, with nearly 1000 patients, conclusively report beneficial effects in the Doppler-guided groups.

In a prospective, randomized controlled trial, Noblett et al. [26] assessed the effect of Doppler-optimized fluid management on outcome after elective colorectal resection. The TED group had a reduced post-operative hospital stay (P=0.043) and tolerated diet earlier (P=0.029). There was a reduced rise in peri-operative level of the IL-6 in

the intervention group (*P*=0.039). The authors concluded that a protocol-based fluid optimization program using intra-operative TED leads to a shorter hospital stay and decreased morbidity in patients undergoing elective colorectal resection.

Also, Chattopadhyay et al. [27] examined the effect of fluid optimization using TED when compared to standard fluid management in women who undergo major gynecological cancer surgery and whether its use is associated with reduced post-operative morbidity. The use of TED was associated with earlier post-operative recovery and earlier fitness for discharge. No significant difference in post-operative complications was noted.

None of the TED studies was actually powered to detect reductions in mortality; however, Chytra et al. [28] observed a trend toward increased survival in multiple-trauma patients managed with Doppler-guided fluid therapy. Nevertheless, a conclusive determination of the role of TED in reducing morbidity and mortality is not yet possible and requires additional and adequately powered studies.

Many studies were designed aiming to investigate the interchangeability of TED and PiCCO monitors like the study was done by Paarmann et al. [29] in patients scheduled for CABG surgery. The study concluded that there was lack of agreement between TED CO measurements and PiCCO monitor during off-pump cardiac surgery and that TED may not be an ideal tool for optimizing haemodynamics to fixed goals for CO or SV in cardiac surgery patients. This result may be due to major problem encountered while using a TED probe is the difficulty to obtain a stable and continuous Doppler signal during surgical manipulation of intrathoracic organs or changes in body position.

Also Feldheiser et al. [30] found that TED and PiCCO monitor were not interchangeable within a goal-directed haemodynamic algorithm with respect to measurement of SV changes to a fluid challenge in patients with metastatic ovarian carcinoma undergoing cytoreductive surgery.

As the PiCCO monitor has the unique ability to measure intrathoracic blood volume (ITBV), extravascular lung water (EVLW), and cardiac function index (CFI). These parameters are of great interest as they are considered to be the most specific measures of cardiac preload, pulmonary edema, contractility, and a global indicator of cardiac performance. Moreover, the main advantages of PiCCO over the PAC is that it is considered to be far less invasive, so that the severe complications attributable to PACs, such as a pulmonary embolism, pulmonary artery rupture and arrhythmia, are less likely to occur. The PiCCO also has the advantage of being suitable for use in paediatrics [31].

While a substantial body of evidence supports the use of TED in guiding volume therapy in surgical patients perioperatively and in the ICU, data concerning non-surgical patients are limited. In addition, the usefulness of TED to guide vasoactive and inotropic therapy in critically ill patients is limited. Moreover, TED cannot measure pulmonary artery pressures as PAC does, nor can it be used to evaluate valvular function as TEE does. Therefore, TED will never be a substitute for all other techniques that measure CO, because each technique also specifically monitors other parameters, which may be of specific interest in certain patient populations [32].

However, the oesophageal Doppler may likely be a rapid, simple and less invasive means of establishing haemodynamic monitoring. It is also invaluable in clinical situations where invasive monitoring may be considered desirable but hazardous, such as in the presence of severe coagulopathy [33].

4. LIMITATION TO OUR STUDY

SVV, or pulse pressure variation, which allows individual titration of the patients' optimal preload. Unfortunately, their major limitations are that they are dependent on controlled mechanical ventilation without any spontaneous breathing effort, and that they are invalid in the presence of arrhythmias. So SVV cant be used, in particular on the ICU when the weaning process from mechanical ventilation was initiated, (TED not in ICU). TED values are dependent on the quality of the signal, which is mainly influenced by an ideal placement of the Doppler probe. The intraoperative data were obtained by more than one investigator involving the risk of an inter-observer variability which could have influenced data collection of the TED values.

5. CONCLUSION

During major abdominal surgery; intraoperative fluid optimization using PiCCO monitor shows

more haemodynamic stability and is associated with a lower rates of postoperative complications, organ dysfunction & infections with a tendency to decrease ICU length of stay in comparison to TED monitor.

6. RECOMMENDATIONS

We do recommend the use of PiCCO monitor on a wider scale of major operations and also compare it with much more devices that measure the cardiac output during operations or in the ICU invasively or less invasively and on a meta-analytic multi-center studies that can give reliable data about patients' haemodynamic status and also postoperative complications.

CONSENT

All authors declare that written informed consents were obtained from all patients before participation & publication of this study. The study was primarily approved by local research ethics' committee.

ETHICAL APPROVAL

All authors herby declare that this study was conducted in the Anaesthesia and Surgical Intensive Care Department, at Theodor Bilharz Research Institute after approval by local research ethics' committee and the study was registered in Pan African Clinical Trial Registry (www.pactr.org) with identification number for the registry PACTR201511001361390.

DISCLAIMER

Conference name: IARS annual meeting.
Date: 21-24 May 2016.
Site: Hilton Union Square, San Francisco, CA. USA.
The link to the final IARS program is:
https://www.iars.org/assets/1/7/16AM_IARS_FP2.pdf
Abstracts number: S-344.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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