ECRONICON OPEN ACCESS

EC ANAESTHESIA
Research Article

Comparison of Electrical Cardiometry and Transoesophageal Doppler for Haemodynamic Monitoring during Living Donor Liver Transplantation: A Randomized Controlled Trial

Eman Sayed Ibrahim[1]*, Nagwa Mohamed Doha[2], Nagwa Ibrahem Mowafy[3], Ashraf Mohamed Mustafa[4] and Khaled Ahmed Yassen[5]

[1]*Assistant Professor of Anaesthesia and ICU, Liver Institute, Menoufia University, Shebeen Elkom, Egypt*

[2]*Assistant Professor of Anaesthesia and ICU, Menoufia University, Shebeen Elkom, Egypt*

[3]*Lecturer of Anesthesia and ICU, Liver Institute, Menoufia University, Shebeen Elkom, Egypt*

[4]*Professor of Anaesthesia and ICU, Menoufia University, Shebeen Elkom, Egypt*

[5]*Professor of Anaesthesia and ICU, Liver Institute, Menoufia University, Shebeen Elkom, Egypt*

***Corresponding Author**: Eman Sayed Ibrahim, Assistant Professor of Anaesthesia and ICU, Liver Institute, Menoufia University, Shebeen Elkom, Egypt.

Received: February 19, 2019; **Published:** March 28, 2019

Abstract

Background: Cardiac output (CO) can be calculated noninvasively with Electrical Cardiometry (EC) utilizing thoracic electrical bio-impedance or minimal invasively with Transesophageal Doppler (TED). Aim was to compare EC to TED regarding (CO), ability to guided fluid administration and monitor haemodynamics during transplantation.

Methods: 47 adult recipients (3 excluded): EC gp, (n = 22) and TED gp (n = 22). Following anaesthesia, TED probe was passed orally into mid-esophagus. Cardiometry skin sensors were applied simultaneously. In EC gp Anaesthetist were blinded to TED and vice versa. 6 ml/kg/h Ringer's acetate, only 3 ml/kg Albumin 5% boluses when stroke volume variation (SVV) (%) in EC > 10% or corrected flow time (FTc) (msec) in TED < 350 msec. Rotational thromboelastometry guided blood products.

Results: Comparable age, weight, graft body weight ratio. An overall good degree of reliability between EC and TED CO, r = 0.928, 95% CI (0.913 - 0.941), p < 0.001. Median (IQR) EC CO was constantly higher than TED CO (l/min). After induction 7.55 [6.70 - 8.50] vs. 6.80 [6.10 - 7.50], p < 0.001, anhepatic: 7.60 [7.20 - 8.50] vs. 6.75 [6.35 - 7.50], p < 0.001, reperfusion: 7.90 [7.10 - 8.60] vs.7.25 [6.50 - 7.85] p < 0.001, end surgery 8.40 [8.00 - 8.80] vs.7.70 [7.25 - 8.20] p < 0.001, respectively. In EC vs. TED. 5500 [5200 - 6000] vs. 5525 [5200 - 6000] ml, p = 0.81 of Crystalloids and 800 [600 - 1000] vs. 850 [800 - 1000] ml, p = 0.2 of Albumin 5% were infused, respectively. FTc negatively correlated with SVV (t) = -0.321, p < 0.001, and both not in correlation with CVP.

Conclusion: The agreement between CO measured by EC and TED is acceptable. Both were able to monitor trend changes and guide fluid administration.

Keywords: *Electrical Cardiometry; Transoesophageal Doppler; Liver Transplantation*

Introduction

Adult living donor liver transplantation, ALDLT can be marked by significant haemodynamic instability requiring the use of a variety of haemodynamic monitors to aide in intraoperative management [1].

ALDLT having three distinct stages: the dissection, the anhepatic phase, and the neohepatic phase. Each stage has its own haemodynamic concerns. The pre-anhepatic phase is when all the dissection occurs, and is marked by significant fluid shifts from drainage of

ascites to the potential for significant blood loss in the presence of varices from portal hypertension [2]. The anhepatic stage is defined as the cessation of blood flow to the native liver until the time of reperfusion of the transplanted liver. With cross clamping of the portal vein and IVC, cardiac output (CO) may decrease by up to 50% [3]. The neohepatic stage is defined as the beginning of reperfusion until the end of the case. Reperfusion is often marked by significant haemodynamic instability due to the rapid return of blood from the previously obstructed portal system and newly transplanted liver. This blood tends to be acidotic, hyperkalemic, cool, and contains a variety of inflammatory and vasodilatory mediators [4]. The result is often a transient but significant decrease in myocardial contractility, chronotropy and systemic vascular resistance [5].

The primary goal of haemodynamic therapy is the prevention of inadequate tissue perfusion and inadequate oxygenation. So advanced cardiovascular monitoring is a prerequisite to optimize haemodynamic treatment in critically ill patients. The most ideal monitor should be reliable, continuous, noninvasive, operator-independent and cost-effective and should have a fast response time [6]. The available CO monitoring techniques can be divided into invasive techniques, minimally invasive techniques, and noninvasive techniques. Transesophageal Doppler (TED) is one of the minimally invasive monitors that allow continuous monitoring of haemodynamic variables. Doppler techniques are commercially available for the estimation of CO by measurement of aortic blood flow (ABF) [7,8].

One of non-invasive and continuously applicable method of CO monitoring is impedance cardiography (ICG). Bioimpedance cardiography is based on the application of a high-frequency, low-alternating electrical current to the thorax. Changes in bioimpedance to this current are related to cardiac events and blood flow in the thorax. The conversion from changes in bioimpedance to stroke volume requires mathematical conversion [9].

Electrical Cardiometry (EC) provides a new algorithm: the Bernstein-Osypka equation to calculate CO [10, 11].

We therefore designed this prospective randomized controlled trial aimed primary to compare the ability of EC and TED to guide perioperative fluid management. The 2ry aim was to test the ability of both techniques to guide perioperative haemodynamic management and refer their effects on postoperative complications in LT recipients.

Patients and Methods

Ethical approval (00123/2017) was provided by the Menoufia University National Liver Institute Review Board (IRB). Written informed consent and the study was registered at the Cochrane research data base of South Africa (PACTR 201701001990415), (www. pactr. org). The study was a single-center; Prospective hospital based randomized controlled double-blind trial carried out in the National Liver Institute which is a tertiary, University affiliated hospital. Forty seven adult recipients age > 18 years scheduled for LDLT were studied between January 2017 and May 2018. Exclusion criteria included recipients with diabetes mellitus, cardiovascular comorbidity, chronic obstructive pulmonary disease; pulmonary dysfunction. PaO_2 less than 60mmHg. Contraindication for oesophageal doppler insertion as (coarctation of the aorta, oesophageal stent, carcinoma of the oesophagus or pharynx, previous oesophageal surgery, oesophageal stricture, pharyngeal pouch, and severe coagulopathy). Patients fulfilled the inclusion criteria were categorized randomly into two equal groups either the Electrical Cardiometry (EC) group or Transoesophageal Doppler (TED) group. The allocation sequence was generated using permuted block randomization technique and the block size was variable. Allocation sequence/code was concealed from the person allocating the participants to the intervention arms using sealed opaque envelopes. Double blinded approach was adopted. Masking/ blinding was employed to participants and statistical analysis team who were blinded to group allocation of patients.

Before induction of anaesthesia four disposable electrocardiographic electrodes were attached at the base of the neck and the inferior aspect of the thorax to record the changing impedance over that area of the thorax. Impedance measurements were obtained with EC (Aesculon Electrical Velocimetry, Osypka Medical GmbH, Berlin, Germany). The Aesculon device emitted a high frequency (50 kHz) and low-amperage (2 mA) alternating electrical current of constant amplitude via a pair of surface electrodes across the left side of the thorax. The voltage drop due to the current application was registered together with the ECG via a second pair of sensing electrodes which were located at the left side of the neck and the left side of the thorax at the level of the xiphoid process, inside the current electrodes.

After standard monitoring was in place, anesthesia was induced using propofol 2 mg kg^{-1} and rocuronium 1.2 mg kg^{-1} to facilitate endotracheal intubation. Anesthesia was maintained via desflurane in O_2/air mixture (FIO_2 = 0.4) and fentanyl. Keeping spectral entropy (GE Healthcare, Helsinki, Finland) between 40% and 60%. Rocuronium was given in intermittent boluses according to the clinical needs.

Following induction of anaesthesia and tracheal intubation, an oesophageal doppler probe (EDM™; Deltex Medical, chichester, UK) was greased with a lubricating gel and passed orally into the mid-oesophagus till aortic blood flow signals were identified. Once achieved, satisfactory, the position was maintained by taping the probe cable to either the patient's face or the endotracheal tube.

Normothermia was achieved with a forced-air warming device. An arterial line was placed in the left radial artery, and a central line was inserted into the right internal jugular vein with a triple-lumen catheter sonar guided. Fluid given included Ringer's acetate solutions (6 mL/kg/h). Terlipressin infusion was titrated (1.0-4.0 μg/kg/hr) or noradrenaline infusion to maintain a mean arterial pressure (MAP) > 65 mmHg and systemic vascular resistance index (SVRI) (1900 - 2400) dyne·s/cm^5/m^2 after adequate volume resuscitation. All patients received intraoperative methylprednisolone (10 mg/kg) during anhepatic phase and if the patient developed postreperfusion hypotension, incremental boluses of ephedrine (2.5 mg) and/or epinephrine (10 μg) each were given to restore haemodynamic stability. Intraoperative blood components transfusion was guided by Rotational thromboelastometry [ROTEM] [12].

Fluid therapy protocol

EC group: Boluses of 3 ml/kg albumin 5% in saline solution were given when stroke volume variation (SVV) rose above 10% (a sustained change during the previous five minutes) [13].

TED group: Boluses of 3 ml/kg albumin 5% in saline solution were given when the FTc was less than 0.35s. If the stroke volume was maintained or increased by the fluid challenge and the FTc remained below 0.35 s, the fluid challenge was repeated. If the stroke volume increased by more than 10% and the FTc exceeded 0.35s, the fluid challenge was repeated until no further increase in stroke volume occurred. If the FTc increased above 0.40s with no change in stroke volume, further fluid was not then administered until the stroke volume decreased by 10% of the last value [14].

The following data were collected; hemodynamic parameters including heart rate and mean arterial blood pressure. (Cardiac output (L/min) (CO), Corrected flow time (msec) (FTc), Stroke volume variation (SVV). The readings of each parameter were taken each hour intraoperative, total amount of vasopressor drugs (ephedrine and noradrenaline), intraoperative transfused fluids, blood products. AST, ALT, bilirubin, INR, serum lactate, and creatinine values were collected at baseline and on postoperative days 1, 3 and 5. Times of postoperative mechanical ventilation and ICU stay, postoperative complication were recorded in all patients.

Sample size calculation: A sample size of 20 patients per group is the enough required sample per group to detect an effect size of 0.7 ± 0.5 liters of the primary outcome (hydroxyethyl starch (HES) (L) [15]. An alpha level was set to 5% with a significance level of 95%, and a beta error accepted up to 20% with a power of study of 80%. The sample size was calculated using IBM SPSS.

Statistical methodology: Data were collected and entered to the computer using SPSS (Statistical Package for Social Science) program for statistical analysis (version 21). Data were described using minimum, maximum, mean, standard deviation and 95% CI of the mean, median and inter-quartile range. Categorical variables were described using frequency and percentage. Comparisons were carried out between two studied independent not-normally distributed subgroups using Mann-Whitney U test. Chi-square test was used to test association between qualitative variables. Intra-class correlation (ICC) was also used to assess agreement. For evaluation of ICC coefficient value Cicchetti guidelines were adopted. Less than 0.40 = poor, between 0.40 and 0.59 = fair, between 0.60 and 0.74 = good, between 0.75 and 1.00 = excellent. The Bland-Altman plot was used. Non-parametric Kendall's tau correlation (τ) was used. Scatter plot and clustered bar chart were used accordingly.

Results

Forty seven LDLT recipients 3 excluded due to severe bleeding and haemodynamic instability were randomized and equally divided into two groups. Patients' characteristics of both groups were comparable. Median age and body mass index (BMI) values were 44.50 [38.00 - 48.00] years, and 26.96 [24.91 - 29.07] kg/m^2 in Electrical Cardiometry group (EC) vs. 45.00 [41.00 - 48.00] years, and 25.82 [24.45 - 27.44] kg/m^2 in Transoesophageal Doppler (TED) group and there were no statistically significant differences between both groups, *P* value < 0.05. Median model of end stage liver disease (MELD) and graft body weight ratio (GBWR) values were 14.50 [13.00 - 15.00] and 1.00 [0.95 - 1.00] in (EC) group vs. 14.00 [12.00 - 15.00] and1.00 [0.98 - 1.10] in (TED) group. Male to female ratio 19/3 in (EC)

group and 19/3 in (TED) group and there were no statistically significant differences between both groups, P value < 0.05 as presented in table 1 and 2.

Variable	Median (IQR)		*P* (value)
	EC group (n = 22)	TED group (n = 22)	
Age (years)	44.50 (38.00 - 48.00)	45.00 (41.00 - 48.00)	0.540 NS
Sex (M/F)	19/3	19/3	NA
BMI (kg/m^2)	26.96 (24.91 - 29.07)	25.82 (24.45 - 27.44)	0.195 NS
MELD	14.50 (13.00 - 15.00)	14.00 (12.00 - 15.00)	0.544 NS
GBWR	1.00 (0.95 - 1.00)	1.00 (0.98 - 1.10)	0.728 NS
Crystalloids(ml)	5500 (5200 - 6000)	5525 (5200 - 6000)	0.810 NS
Colloids (L)	800 (600 - 1000)	850. (800 - 1000)	0.204 NS
FFPs (Units)	4.00 (4.00 - 6.00)	6.00 (4.00 - 6.00)	0.408 NS
RBCs (Units)	4.00 (3.00 - 6.00)	4.00 (2.50 - 6.00)	0.740 NS
Cryoprecipitate (Units)	9.00 (6.00 - 24.00)	12.00 (6.00 - 24.00)	0.939 NS
NE (No .of patients)	5 (22.7%)	5 (22.7%)	NA
Mechanical Ventilation (hrs.)	16.00 (15.00 - 20.00)	17.50 (15.00 - 20.00)	0.710 NS

Table 1: *Patients characteristics and perioperative clinical data.*

Data were presented as Median (IQR); IQR: Inter-quartile range tested by Mann - Whitney U test; or as % tested by X^2 Chi square test; P - value < 0.05 statistically significant. EC: Electrical Cardiometry; TED: Transesophageal Doppler; BMI: Body Mass Index; MELD: Model for End Stage Liver Disease; GBWR: Graft Body Weight Ratio; FFPs: Fresh Frozen Plasma; RBCs: Red Blood Cells; NE: Norepinephrine; NS: Not Significant; No: Number of Patients; NA: Not Applicable.

Variable	Median (IQR)		*p* (value)
	EC group (n = 22)	TED group (n = 22)	
Urea (mg/dl)			
Preoperative	23.00 (20.00 - 28.00)	23.00 (19.00 - 25.00)	0.628 NS
POD 1	45.00 (41.00 - 58.00)	69.50 (53.00 - 78.00)	0.539 NS
POD 3	70.50 (60.00 - 85.00)	69.00 (55.00 - 85.00)	0.724 NS
POD 5	54.00 (38.00 - 80.00)	49.00 (38.00 - 86.00)	0.823 NS
Creatinine (mg/dl) Preoperative	0.80 (0.60 - 1.00)	0.70 (0.60 - 0.90)	0.435 NS
POD 1	1.20 (1.00 - 1.40)	1.00 (0.60 - 1.30)	0.100 NS
POD 3	1.00 (0.90 - 1.20)	1.00 (0.80 - 1.20)	0.627 NS
POD 5	0.90 (0.50 - 1.00)	0.70 (0.50 - 1.00)	0.270 NS
Lactate (mg/dl) Preoperative	19.00 (13.00 - 21.00)	16.00 (13.00 - 19.00)	0.972 NS
POD 1	50.00 (24.00 - 57.00)	33.50 (23.00 - 36.00)	0.805 NS
POD 3	15.50 (10.00 - 28.00)	19.00 (15.00 - 22.00)	0.742 NS
POD 5	13.00 (11.00 - 18.00)	16.00 (13.00 - 19.00)	0.888 NS

Table 2: *Laboratory investigation in the two study groups.*

Data were presented as Median (IQR); IQR: Inter-quartile Range Tested by Mann-Whitney U test; P-value < 0.05 Statistically Significant; EC: Electrical Cardiometry; TED Transesophageal Doppler; Post-Operative Day (POD1); POD3; POD5; NS: Not Significant.

An overall good degree of reliability between EC and TED CO (440 pairs) (Intraclass correlation = 0.928, 95% CI (0.913 - 0.941); p < 0.001. with an overall mean bias difference (95% confidence) (n = 396) of 0.697 (0.6616 - 0.7323); p < 0.001 (Bland and Altman) .Median (IQR) EC CO was constantly higher than TED CO (l/min). After induction was 7.55 (6.70 - 8.50) vs. 6.80 (6.10 - 7.50); p < 0.001, anhepatic was 7.60 (7.20 - 8.50) vs. 6.75 (6.35 - 7.50); p < 0.001, reperfusion was 7.90 (7.10 - 8.60) vs.7.25 (6.50 - 7.85) p < 0.001, end surgery was 8.40 (8.00 - 8.80) vs.7.70 (7.25 - 8.20); p < 0.001, respectively. Both CO increased after reperfusion (Repeated measure ANOVA; p < 0.001. FTc, SVV and central venous pressure (CVP) were comparable. In EC vs. TED total amount of crystalloids were 5500 (5200 - 6000) vs. 5525 (5200 - 6000) ml; p = 0.81. Total amount of albumin 5% was 800 (600 - 1000) vs. 850 (800 - 1000) ml; p = 0.2 respectively. FTc negatively correlated with SVV (440 pairs). Kendall tau correlation (t) = -0.321; p < 0.001, and both not in correlation with CVP. Diathermy interfered with both and TED probes required repositioning. The number of patients who needed norepinephrine were the same in both group (n = 5) 22.75%. Number of patient suffered from Post-operative complications, wound infection, pneumonia, ventilator support, arrhythmias, heart failure, deep venous thrombosis and post-operative nausea and vomiting were 0, 3, 0, 0, 0, 0 and 6 in EC group vs. 0, 5, 2, 0, 0, 0 and 8 in TED and there were no statistically significant differences between both groups *P* value > 0.05 as presented in table 3. Regarding median ICU Stay, it was 5 (5 - 6) in EC group vs. 5 (5-6) in TED group and there was no statistically significant differences between both groups; P value > 0.05.

Variable	Median (IQR)		*p* (value)
	EC group (n = 22)	TED group (n = 22)	
AST (IU/L)			
Preoperative	38.50 (35.00 - 75.00)	40.00 (37.00 - 79.00)	0.435 NS
POD1	255.00 (170.0 - 626.0)	232.00 (171.00 - 539.00)	0.100 NS
POD 3	137.50 (95.00 - 391.00)	128.00 (93.00 - 376.00)	0.627 NS
POD 5	62.50 (52.00 - 107.00)	56.50 (53.00 - 109.00)	0.270 NS
ALT (IU/L)			
Preoperative	32.00 (26.00 - 37.00)	34.50 (30.00 - 39.00)	0.518 NS
POD 1	256.50 (194.0 - 797.0)	247.50 (197.00 - 681.00)	0.769 NS
POD 3	198.50 (148.0 - 743.0)	194.50 (147.00 - 709.00)	0.787 NS
POD 5	138.00 (99.00 - 396.00)	122.00 (102.00 - 391.00)	0.796 NS

Table 3: *Serum aspartate aminotransferase and alanine aminotransferase levels IU/L in the two study groups.*

Data were presented as Median (IQR); IQR: Inter-quartile Range Tested by Mann-Whitney U test; P-value < 0.05 Statistically Significant; EC: Electrical Cardiometry; TED: Transesophageal Doppler; Post-Operative Day (POD1); POD3; POD5; NS: Not Significant; AST: Serum Aspartate Aminotransferase Levels (IU/L); Serum Alanine Aminotransferase Level IU/L; NS: Not Significant.

	EC group (n = 22)	TED group (n = 22)	Test of significance *p* (value)
Wound infection	0 (0.00%)	0 (0.00%)	NA
Pneumonia	3 (13.63%)	5 (22.72%)	$X^2_{(Y)} = 0.153$, $p_{(Y)} = 0.696$ NS
Ventilator support	0 (0.00%)	2 (9.09%)	$X^2_{(Y)} = 0.524$, $p_{(Y)} = 0.469$ NS
Arrhythmias	0 (0.00%)	0 (0.00%)	NA
Heart failure	0 (0.00%)	0 (0.00%)	NA
DVT	0 (0.00%)	0 (0.00%)	NA
PONV	6 (27.27%)	8 (36.36%)	$X^2 = 0.419$, p = 0.17 NS

Table 4: *Frequency of Post-operative complications.*

Data was presented as number of patients and % tested by X^2 Chi square test; Y: Yate's (continuity correction) for Chi-square and its p value; DVT: Deep Venous Thrombosis; PONV: Post-operative nausea and vomiting; NS: Not Significant; NA: Non-applicable statistics due to exact match.

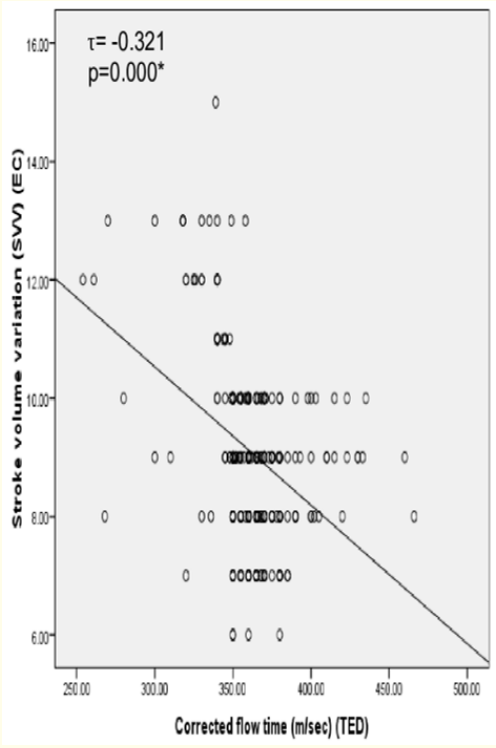

Figure 1: *Scattered Plot graph of stroke volume variation (SVV) from EC and corrected flow time (m/sec) from TED. EC: Electrical Cardiometry; TED: Transesophageal Doppler.*

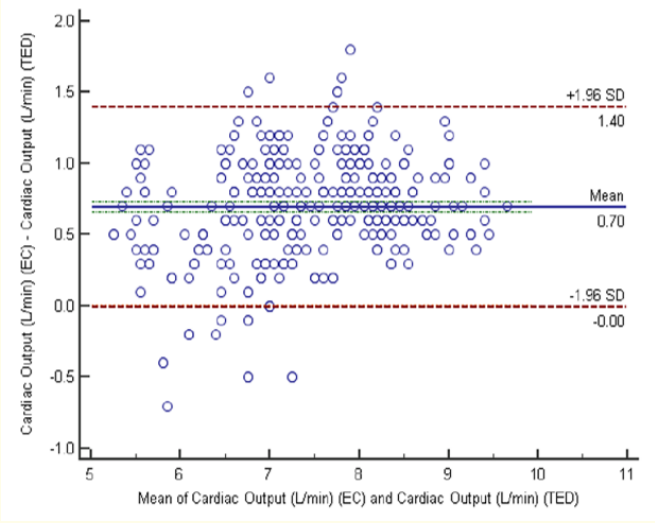

Figure 2: *Bland Altman Analysis of degree of agreement between EC-CO and TED-CO. X-axis-mean CO from EC and TED [(TED-CO + EC-CO)]/2 and Y-axis-CO difference (ECCO-TEDCO). CO = cardiac output (L/min). EC: Electrical Cardiometry; TED: Transesophageal Doppler.*

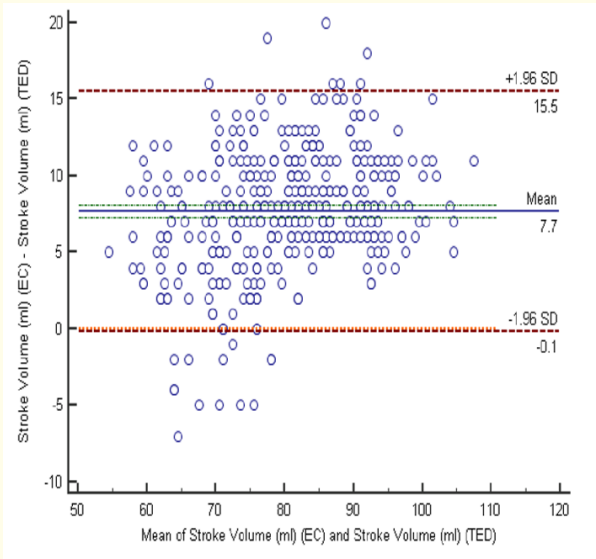

Figure 3: *Bland Altman analysis of degree of agreement between EC-SV and TED-SV. X-axis-mean SV from EC and TED [(TED-SV + EC-SV)]/2 and Y-axis-SV difference (ECSV-TEDSV). SV = stroke volume (ml). EC: Electrical Cardiometry; TED: Transesophageal Doppler.*

Discussion and Conclusion

The major observation in our study was that the agreement between CO measured by EC and TED is acceptable. Both were able to monitor trend changes and guide fluid administration during ALDLT .The use of invasive tool as pulmonary artery catheter PAC for monitoring the CO during the liver transplant procedure is declining during the last decade in many transplant centers world-wide as evident from several published article, with the introduction of other less invasive alternative technologies to help trace changes in CO and systemic haemodynamic parameters during the different phases of the transplantation [16,17]. Few published research projects investigated the role of TED and EC during liver transplantation, a procedure known to be accompanied with significant changes in CO and SVR [17,18]. The need to develop and to test these new technological alternatives to invasive PA monitoring was always needed in an effort to reduce the incidence of the associated PAC related complications particularly in critically ill patients [19-21]. During the last decade several alternative technologies for monitoring CO were developed further and became more practical to use as EC and TED, both were tested against the measured CO by the standard thermodilution technique of PAC and both were approved after their practical use in various surgery and among critical care patients but few research projects were reported among liver transplant recipients [11,22,23]. The results of our study demonstrated the clearly ability of both EC and TED to monitor noninvasively the expected trend changes of CO with time during the different phases of the transplantation particularly at the crucial moments of the reperfusion phase when the new liver graft is introduced for the first time to the recipient blood circulation as evident in results. In this current study it was also noticed that EC CO was consistently slightly higher than TED CO, but the bias which is the mean CO difference between the 2 techniques was found to be reasonable and with an acceptable precision (±SD) in favor of their agreement. This could be explained by the position of the TED probes in the lower oesophageus facing the descending aorta; this position could underestimate CO due to the absence of cerebral and upper limb blood flow in this part of aorta [24]. As a reflection of this the calculated SVR in our study was consistently higher than the TED, but within acceptable precision. EC and TED were previously tested by several researchers in various and different circumstances and most of them agree that following the trend of CO changes is considered acceptable, and that more modifications is required to reach with the absolute value of their CO to a close value to that obtained by the PAC [11,23]. Similar results were observed by Ashraf M., *et al*. and E Lorne working group [25,26]. TED can be a helpful tool to guide fluid therapy and inotropic support both intraoperative and in the intensive care unit, but cannot be considered interchangeable with PAC TDT for measuring absolute CO [24]. The reason why individual CO measurements obtained with TED may differ compared with PAC TDT can be explained. TED CO measurements is being based on several assumptions which includes that the amount of blood flow through the descending aorta is at a fixed percentage of CO which is not

true particularly in clinical situations as shock in which the percentage split of flow between the upper and lower body can be modified [24]. The aortic cross-sectional area can be one of the major contributors of error in TED CO values. To overcome this source of error, TED uses the minute distance (= time velocity integral multiplied by heart rate) measured in the descending aorta as a surrogate for CO, without the need to measure the cross sectional area [27,28]. The acceptability of using Transoesophageal Doppler CO measurements to track relative changes in CO had been supported by several perioperative adult studies during liver transplantation, aortic surgery, and major abdominal surgery [29-31]. Furthermore, Vishwas M and his colleagues and Randhir Singh Rajput., *et al.* were able to demonstrate an acceptable degree of agreement between EC and the continuous thermodilution cardiac output [11,22]. A good agreement between EC and transthoracic echocardiography for determining left ventricular stroke volume [32,33,35]. Magliocca A., *et al.* working group who have a different opinion that noninvasive CO estimation with EC exhibited limited accuracy and precision particularly when SVR decreases, but they also observed that the CO values when compared to the thermodilution technique (TDT) CO, during surgery demonstrated a reasonable trending ability [35]. Lack of agreement between thermodilution and EC cardiac output measurements was observed when used in cardiac surgery during cardiopulmonary bypass and moderate hypothermia. Heringlake M., *et al.* searching for an explanation for these discrepancies they found that the raw impedance signals in their series of patients were disturbed by electrical artifacts. The electrical artifacts in the impedance tracings remained detectable even after changing the type of ECG electrodes and after disconnecting the patients from other electrical devices as well as ruling out shivering by means of neuromuscular blockade [36].

Other factors leading to unreliable readings of CO had been reported by other researchers, from those the position of the electrodes and a body weight 15% greater than the ideal weight [37,38]. This current study demonstrated that a comparable total average amount of fluids infused in the EC guided fluid and TED groups with a similar incidence of postoperative complication (Pneumonia, ventilator support, post-operative nausea and vomiting).This indicates that both FTc of TED and SVV of EC can be used interchangeable to guided fluid management successfully. Excessive intraoperative fluid transfusion was associated with postoperative pulmonary complications, prolonged postoperative recovery unit stay and extubation time [39,40]. SVV-based guided fluid management during major orthopedic surgery reduced the volume of the required intraoperative infused fluids, maintained intraoperative haemodynamic stability, and improved the perioperative gastrointestinal function [41]. Also Jan Benes and his colleague in their study found similar result in high risk surgical patients and concluded that fluid optimization guided by SVV during major abdominal surgery is associated with better intraoperative haemodynamic stability, decrease in serum lactate at the end of surgery and lower incidence of postoperative organ complications [13]. Also Srivastava D and his colleague concluded that FTc-guided intraoperative fluid therapy achieved the same rate of immediate graft function as CVP-guided fluid therapy and the use of TED may replace invasive central line insertions [42]. This could lead to the establishment of new guided protocols for fluid replacement in this category of hepatic patients during their perioperative period based on a minimal invasive technique as Transoesophageal Doppler with monitoring the corrected aortic flow time as a guide for fluid replacement or cardiometry with monitoring of SVV without the need for invasive monitoring, but still remains the challenge to monitor postoperative spontaneous breathing patient.

In conclusion the agreement between CO measured by EC and TED is acceptable. Both were able to monitor trend changes and guide fluid administration.

Funding

None.

Conflict of Interest

None declared.

Registration Number

Ethical approval (00123/2017) was provided by the Menoufia University National Liver Institute Review Board (IRB). The study was registered at the Cochrane research data base of South Africa (PACTR 201701001990415), (www. pactr.org).

Bibliography

1. Mona Rezai Rudnick., *et al*. "Haemodynamic monitoring during liver transplantation: A state of the art review". *World Journal of Hepatology* 7.10 (2015): 1302-1311.

2. Amy C Robertson and Susan S Eagle. "Transesophageal echocardiography during orthotopic liver transplantation: maximizing information without the distraction". *Journal of Cardiothoracic and Vascular Anesthesia* 28.1 (2014): 141-154.

3. Schumann R. "Intraoperative resource utilization in anaesthesia for liver transplantation in the United States: a survey". *Anesthesia and Analgesia* 97.1 (2003): 21-28.

4. Ozier Y and Klinck JR. "Anaesthetic management of hepatic transplantation". *Current Opinion in Anesthesiology* 21.3 (2008): 391-400.

5. Bukowicka B., *et al*. "The occurrence of postreperfusion syndrome in orthotopic liver transplantation and its significance in terms of complications and short-term survival". *Annals of Transplantation* 16.2 (2011): 26-30.

6. De Waal., *et al*. "Cardiac output monitoring". *Current Opinion in Anaesthesiology* 22.1 (2009): 71-77.

7. Monsel A., *et al*. "The transesophageal doppler and haemodynamic effects of epidural anesthesia in infants anesthetized with sevoflurane and sufentanil". *Anesthesia and Analgesia* 105.1 (2007): 46-50.

8. Monnet X., *et al*. "Measuring aortic diameter improves accuracy of oesophageal doppler in assessing fluid responsiveness". *Critical Care Medicine* 35.2 (2007): 477-482.

9. De Waal EE., *et al*. "Assessment of stroke volume index with three different bioimpedance algorithms: lack of agreement compared to thermodilution". *Intensive Care Medicine* 34.4 (2008): 735-739.

10. Zoremba N., *et al*. "Comparison of electrical velocimetry and thermodilution techniques for the measurement of cardiac output". *Acta Anaesthesiologica Scandinavica* 51.10 (2007): 1314-1319.

11. Randhir Singh Rajput., *et al*. "Comparison of cardiac output measurement by noninvasive method with electrical cardiometry and invasive method with thermodilution technique in patients undergoing coronary artery bypass grafting". *World Journal of Cardiovascular Surgery* 4.7 (2014): 123-130.

12. Saner FH., *et al*. "Delicate balance of bleeding and thrombosis in end-stage liver disease and liver transplantation". *Digestion* 88.3 (2013): 135-144.

13. Benes J., *et al*. "Intraoperative fluid optimization using stroke volume variation in high risk surgical patients: results of prospective randomized study". *Critical Care* 14.3 (2010): R118.

14. Sinclair S., *et al*. "Intraoperative intravascular volume optimisation and length of hospital stay after repair of proximal femoral fracture: randomised controlled trial". *British Medical Journal* 315.7113 (1997): 909-912.

15. El Sharkawy OA., *et al*. "Transoesophageal doppler compared to central venous pressure for perioperative haemodynamic monitoring and fluid guidance in liver resection". *Saudi Journal of Anaesthesia* 7.4 (2013): 378-386.

16. Nissen P., *et al*. "Techniques of cardiac output measurement during liver transplantation: arterial pulse wave versus thermodilution". *Liver Transplantation* 15.3 (2009): 287-291.

17. Spiess BD., *et al*. "Bioimpedance haemodynamics compared to pulmonary artery catheter monitoring during orthotopic liver transplantation". *Journal of Surgical Research* 54.1 (1993): 52-56.

18. Hussien M., *et al*. "Use of transesophageal doppler as a sole cardiac output monitor for reperfusion haemodynamic changes during living donor liver transplantation: An observational study". *Saudi Journal of Anaesthesia* 5.3 (2011): 264-269.

19. Schoenfeld D., *et al*. "Pulmonary-artery versus central venous catheter to guide treatment of acute lung injury". *New England Journal of Medicine* 354.21 (2006): 2213-2224.

20. Zöllner C., *et al*. "Continuous cardiac output measurements do not agree with conventional bolus thermodilution cardiac output determination". *Canadian Journal of Anesthesia* 48.11 (2001): 1143-1147.

21. Mihm FG., *et al*. "A multicenter evaluation of a new continuous cardiac output pulmonary artery catheter system". *Critical Care Medicine* 26.8 (1998): 1346-1350.

22. Vishwas Malik., *et al*. "Correlation of electric cardiometry and continuous thermodilution cardiac output monitoring systems". *World Journal of Cardiovascular Surgery* 4.7 (2014): 101-108.

23. Knirsch W., *et al*. "Comparison of cardiac output measurement using the Cardio Q oesophageal doppler with cardiac output measurement using thermodilution technique in children during heart catheterization". *Intensive Care Medicine* 34.6 (2008): 1060-1064.

24. Møller-Sørensen H., *et al*. "Transesophageal doppler reliably tracks changes in cardiac output in comparison with intermittent pulmonary artery thermodilution in cardiac surgery patients". *Journal of Clinical Monitoring and Computing* 31.1 (2017): 135-142.

25. Ashraf M Moustafa., *et al*. "Electrical cardiometry compared to transoesophageal doppler for perioperative haemodynamic monitoring and fluid management in pediatrics undergoing kasai operation". American Society of Anesthesiologists (2017).

26. Lorne E., *et al*. "Accuracy of impedance cardiography for evaluating trends in cardiac output: a comparison with oesophageal Doppler". *British Journal of Anaesthesia* 113.4 (2014): 596-602.

27. Tibby SM., *et al*. "Use of transesophageal doppler ultrasonography in ventilated pediatric patients: derivation of cardiac output". *Critical Care Medicine* 28.6 (2000): 2045-2050.

28. Murdoch IA., *et al*. "Continuous haemodynamic monitoring in children: use of transoesophageal Doppler". *Acta Paediatrica* 84.7 (1995): 761-764.

29. Green DW. "Comparison of cardiac outputs during major surgery using the Deltex CardioQ oesophageal Doppler monitor and the Novametrix-Respironics NICO: a prospective observational study". *International Journal of Surgery* 5.3 (2007): 176-182.

30. Moira McKendry., *et al*. "Randomized controlled trial assessing the impact of a nurse delivered, flow monitored protocol for optimization of circulatory status after cardiac surgery". *British Medical Journal* 329 (2004): 258.

31. Chew MS and Poelaert J. "Accuracy and repeatability of pediatric cardiac output measurements using Doppler: 20-year review of the literature". *Intensive Care Medicine* 29.11 (2003): 1889-1894.

32. Neurinda P Kusumastuti and Masaki Osaki. "Electric velocimetry and transthoracic echocardiography for noninvasive cardiac output monitoring in children after cardiac surgery". *Critical Care and Shock* 18 (2015): 36-42.

33. Blohm ME., *et al*. "Impedance cardiography (electrical velocimetry) and transthoracic echocardiography for non-invasive cardiac output monitoring in pediatric intensive care patients: a prospective single-center observational study". *Critical Care* 18.6 (2014): 603.

34. Schmidt C., *et al*. "Comparison of electrical velocimetry and transoesophageal doppler echocardiography for measuring stroke volume and cardiac output". *British Journal of Anaesthesia*95.5 (2005): 603-610.

35. Magliocca A., *et al*. "Cardiac output measurements based on the pulse wave transit time and thoracic impedance exhibit limited agreement with thermodilution method during orthotopic liver transplantation". *Anesthesia and Analgesia* 126.1 (2018): 85-92.

36. Heringlake M., *et al*. "Lack of agreement between thermodilution and electrical velocimetry cardiac output measurements". *Intensive Care Medicine* 33.12 (2007): 2168-2172.

37. van der Meer BJ., *et al*. "PM Impedance cardiography: importance of the equation and the electrode configuration". *Intensive Care Medicine* 22.10 (1996): 1120-1124.

38. Van der Meer BJ., *et al*. "Impedance cardiography in cardiac surgery patients: abnormal body weight gives unreliable cardiac output measurements". *Acta Anaesthesiologica Scandinavica* 41.6 (1997): 708-712.

39. Jiang GQ., *et al*. "Individualized peri-operative fluid therapy facilitating early phase. recovery after liver transplantation". *World Journal of Gastroenterology* 18.16 (2012): 1981-1986.

40. Calvo-Vecino JM., *et al*. "Effect of goal-directed haemodynamic therapy on postoperative complications in low-moderate risk surgical patients: a multicentre randomized controlled trial". *British Journal of Anaesthesia* 120.4 (2018): 734-744.

41. Peng K., *et al*. "Goal-Directed fluid therapy based on stroke volume variations improves fluid management and gastrointestinal perfusion in patients undergoing major orthopedic surgery". *Medical Principles and Practice* 23.5 (2014): 413-420.

42. Srivastava D., *et al*. "Effect of intraoperative transesophageal Doppler guided fluid therapy versus central venous pressure guided fluid therapy on renal allograft outcome in patients undergoing living donor renal transplant surgery: a comparative study". *Journal of Anaesthesia* 29.6 (2015): 842-849.

Volume 5 Issue 4 April 2019