

- [consultado 3 Jun 2021]. Disponible en: <http://medrxiv.org/content/early/2021/05/11/2021.04.27.21256153.abstract>. DOI: <https://doi.org/10.1101/2021.04.27.21256153>
4. Greinacher A, Thiele T, Warkentin TE, Weisser K, Kyrle PA, Eichinger S. Thrombotic thrombocytopenia after ChAdOx1 nCoV-19 vaccination. *N Engl J Med.* 2021;384:2092–101. <http://dx.doi.org/10.1056/NEJMoa2104840>.
  5. Scully M, Singh D, Lown R, Poles A, Solomon T, Levi M, et al. Pathologic antibodies to platelet factor 4 after ChAdOx1 nCoV-19 vaccination. *N Engl J Med.* 2021;384:2202–11. <http://dx.doi.org/10.1056/NEJMoa2105385>. NEJMoa2105385.
  6. Federación de Asociaciones Científico Médicas Españolas (FACME). Recomendaciones para el diagnóstico y tratamiento de eventos trombóticos tras la vacunación frente a Covid-19. 2021 [consultado 3 Jun 2021]. Disponible en: <https://facme.es/wp-content/uploads/2021/04/VACUNAS-COVID-Y-EVENTOS-TROMBOC2%B4TICOS-FACME-V4.25-FINAL.pdf>.
  7. Ministerio de Sanidad. Informe de actividad del proceso de vacunación. 2021 [consultado 3 Jun 2021]. Disponible en: [https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov/documentos/Informe\\_GIV\\_comunicacion\\_20210430.pdf](https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov/documentos/Informe_GIV_comunicacion_20210430.pdf).
  8. 5.º Informe de Farmacovigilancia sobre vacunas de la Agencia Española de Medicamentos y Productos Sanitarios (AEMPS), 2021 [consultado 3 Jun 2021]. Disponible en: <https://www.aemps.gob.es/informa/boletines-aemps/boletin-fv/2021-boletin-fv/5o-informe-de-farmacovigilancia-sobrevacunas-covid-19/#astrazeneca>.
  9. American Heart Association/American Stroke Association Stroke Council Leadership. Diagnosis and management of cerebral venous sinus thrombosis with vaccine-induced thrombotic thrombocytopenia. *Stroke.* 2021;52:2478–82. DOI 10.1161/STROKEAHA.121.035564.

G. Morales Varas\*, A. Calle Flores y M. Sánchez Casado

*Unidad de Cuidados Intensivos, Servicio de Medicina Intensiva, Complejo Hospitalario Universitario de Toledo, Toledo, España*

\* Autor para correspondencia.

Correo electrónico: [guillermo.moralesvaras@gmail.com](mailto:guillermo.moralesvaras@gmail.com) (G. Morales Varas).

<https://doi.org/10.1016/j.medin.2021.07.003>

0210-5691/ © 2021 Elsevier España, S.L.U. y SEMICYUC. Todos los derechos reservados.

## Hemodynamic monitoring for liver transplantation: Agreement between invasive and non-invasive devices?



### Monitorización hemodinámica para trasplante de hígado: ¿concordancia entre dispositivos invasivos y no invasivos?

Dear Editor,

Liver transplantation (LT) is characterized by bleeding, circulatory volume fluctuations, vascular clamping/unclamping and major fluid shifts, resulting in significant circulatory instability.<sup>1</sup> A meta-analysis conducted by Cecconi et al. concluded that hemodynamic monitoring strategies coupled with therapy decisions, reduces mortality in high-risk surgical patients.<sup>2</sup> Invasive thermodilution has long been the gold standard in estimating cardiac output (CO).<sup>3</sup> As an easy-to-use noninvasive device, NICOM<sup>®</sup> uses thoracic bioactance to analyze the variations in voltage in each cardiac contraction in response to high-frequency current. Previous studies have shown mixed results regarding the performance of bioactance for measuring CO in various populations.<sup>4–6</sup> We aimed to evaluate whether bioactance can be used as an alternative CO monitoring technique in liver transplantation.

We performed a prospective non-randomized study from September to November 2019 and recruited all patients admitted for elective LT. Re-transplants or emergency LT were excluded. All patients had a Pulse Contour Cardiac Output (PiCCO<sup>®</sup>) device placed in the femoral artery and a central venous catheter placed in the internal jugular vein according to the established transplant's protocol.

After LT surgery, patients were sequentially included for placing a Cheetah Medical NICOM<sup>®</sup> device. Cardiac index (CI) was recorded at admission and every 8 h during the first 48 h. CI recorded from PiCCO<sup>®</sup> was measured three times using the transpulmonary thermodilution technique and after injecting 20 mL boluses of cold normal saline via a central venous catheter. System was calibrated before each group of measurements and performed by the same person. If the variation among readings was higher than 10%, one additional measurement was taken for an average reading. Data was expressed as mean values and standard deviation (SD). The difference in CO between the two techniques was calculated as the mean  $\pm$  1.96  $\times$  SD which were called 95% limits of agreement; the percentage error was calculated using the formula  $(100 \times 1.96 \times SD \text{ of bias between the two methods}) / \text{mean between the two methods}$ . Mean percentage error was considered acceptable if  $<30\%$ . Correlations were tested using the Pearson correlation coefficient. Agreement between thermodilution/bioreactance was tested using Bland–Altman analysis and intraclass correlation coefficient (ICC).<sup>5–7</sup> Conclusions obtained from bioactance did not influence medical decisions. Institution Ethics Committee approved the study.

Twenty-nine patients were recruited but only 20 fulfilled the inclusion criteria. A total of 420 paired observations were collected as described in Table 1. After LT, as a result of fluid resuscitation, cumulative fluid balance increased as well as ELWI measurements. There was good agreement between thermodilution-CI and bioactance-CI ( $3.44 \pm 0.87$  versus  $3.51 \pm 0.738$ , L/min/m<sup>2</sup>) at ICU admission, with a mean bias of  $-0.076$  L/min/m<sup>2</sup> and an ICC of 0.974 (95% confidence interval 0.932–0.990,  $P < 0.05$ ). The mean percentage error between the two methods was  $\pm 14\%$ . There

**Table 1** Postoperative clinical data after liver transplant.

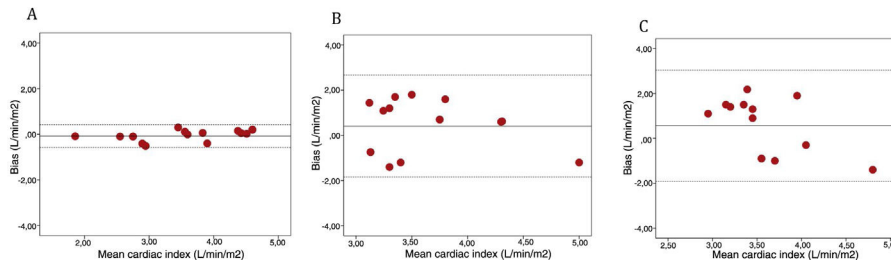
Variables	Values		
Age, years	52 [9.4]		
Male/female	6/4		
Ideal body index, kg/m <sup>2</sup>	23.8 [1.7]		
Main reasons for LT, number (%)			
Liver cirrhosis	14 (70%)		
Hepatocellular carcinoma	6 (30%)		
Tympanic temperature, °C	36.3 [0.4]		
Admission noradrenaline support, mcrg/kg/min	0.70 [0.77]		
Previous pleural effusion, number (%)	2 (10%)		
Fluid balance, mL			
8 h	1776 [1684]		
16 h	3403 [1877]		
24 h	3722 [1875]		
32 h	4280 [1548]		
40 h	4197 [1460]		
48 h	4477 [1761]		
Variables	Thermodilution	NICOM	P-value
Cardiac index, L/min/m <sup>2</sup>			
0 h	3.44 [0.870]	3.51 [0.738]	0.494
8 h	3.77 [0.827]	3.42 [0.483]	0.124
16 h	3.85 [1.21]	3.65 [1.04]	0.195
24 h	3.77 [0.731]	3.38 [0.856]	0.255
32 h	3.86 [0.509]	3.21 [1.25]	0.078
40 h	3.85 [0.545]	3.25 [1.17]	0.109
48 h	3.87 [0.449]	3.2 [1.17]	0.080
ELWI, mL/kg			
0 h	7.73 [1.79]	-	-
8 h	8.50 [1.86]		
16 h	8.81 [2.08]		
24 h	9.21 [1.88]		
32 h	9.5 [1.90]		
40 h	9.5 [1.65]		
48 h	8.9 [1.21]		
CI agreement	0 h	24 h	48 h
Bias and limits of agreement	-0.076 (-0.199 to 0.047)	0.411 (-1.843 to 2.67)	0.560 (-1.914 to 3.034)
ICC (95% confidence interval)	0.974 (0.932 to 0.990)	-0.115 (-1.983 to 0.611)	-0.630 (-3.396 to 0.470)
Correlation (r, P-value)	0.167, P<0.05	-0.276, P=0.644	-1.522, P<0.05
Mean percentage error	±14%	±61%	±69%

CI: cardiac index; ELWI: extra lung water index; ICC: intraclass correlation coefficient; LT: liver transplant. Continuous variables were presented as mean and standard deviation (SD). Independent data was compared using Student's unpaired *t*-test. Correlations were tested using the Pearson correlation coefficient. We calculated the percentage error between CI measurements using the following formula: mean percentage error = (100 × 1.96 × SD of bias between the two methods)/mean between the two methods. Mean percentage error was considered acceptable if <30%.

was a strong correlation between thermodilution-CI and bioreactance-CI (Table 1 and Fig. 1). Over time, CI measurements were progressively different in both devices and mean percentage error was >30% (Table 1).

Non-invasive CI monitoring by the bioreactance technique has gained considerable interest recently. In patients after cardiac surgery, NICOM® had good agreement with thermodilution, the currently accepted gold standard.<sup>3,4</sup>

Our results suggest that after the first hours, NICOM® was a valid method for assessing CI, when compared with CI measured by invasive thermodilution. The mean percentage error obtained in the first measure was 14%, which is less than the recommended cut-off of 30%. However, over time, we consistently observed percentage errors >50%, which doubts its use. Bioreactance depends on the analysis of the difference in high-frequency current signal that



**Figure 1** Bland–Altman analysis of cardiac output measured at Intensive Care Unit admission (A), after 24 h (B) and after 48 h (C) of monitoring.

traverses the thoracic cavity, which is influenced by the amount of fluids in the thorax.<sup>3</sup> In our population, cumulative fluid balance during the first two days, associated with a high ELWI may have interfered with signal reception and CI calculation. For this reason, we excluded 9 patients with acute phase disturbs (re-transplants or urgent LT) as a way to reduce bias. Furthermore, our study’s interpretations were limited by a relatively small sample size and the absence of NICOM® measurements during surgery. Hemoglobin concentration and hematocrit values should be taken into count as they may increase the bias between the two methods.

In sum, our observation showed unacceptable agreement between bioreactance and thermodilution for assessing CI in the postoperative phase of LT. Thus, in this population, bioreactance as a substitute to thermodilution in spite of its noninvasiveness, did not reveal to be an alternative.

### Funding

No sources of funding for the present paper were used.

### Conflict of interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

### Bibliografía

1. Della Rocca G, Chiarandini P. Hemodynamic monitoring during liver transplantation. *Int Anesthesiol Clin.* 2017;55:121–34.
2. Hamilton MA, Cecconi M, Rhodes A. A systematic review and meta-analysis on the use of preemptive hemodynamic intervention to improve postoperative outcomes in moderate and high-risk surgical patients. *Anesth Analg.* 2011;112:1392–402.

3. Han S, Lee JH, Kim G, Sangwook Ko J, Gwak MS. Bioreactance is not interchangeable with thermodilution for measuring cardiac output during adult liver transplantation. *PLOS ONE.* 2015;10:e12781.
4. Shih P-Y, Lin W-Y, Hung M-H, Cheng Y-J, Chan K-C. Evaluation of cardiac output by bioreactance technique in patients undergoing liver transplantation. *Acta Anaesthesiol Taiwanica.* 2016;54:57–61.
5. Odor PM, Bampoe S, Cecconi M. Cardiac output monitoring: validation studies – how results should be presented. *Curr Anesthesiol Rep.* 2017;7:410–5.
6. Doherty A, Monteith C, Mcsweeney L, Breatnach C, Kent E, Tully E, et al. Comparison of bioreactance and echocardiographic non-invasive cardiac output monitoring and myocardial function assessment in primigravida women. *Br J Anaesth.* 2017;118:527–32.
7. Squara P, Denjean D, Estagnasie P, Brusset A, Dib J, Dubois C. Noninvasive cardiac output monitoring (NICOM): a clinical validation. *Intensive Care Med.* 2007;33:1191–4.

T. Isidoro Duarte<sup>a,\*</sup>, M. Amaral<sup>b</sup>, C. Pires<sup>a</sup>, J. Casimiro<sup>a</sup>, N. Germano<sup>a</sup>

<sup>a</sup> *Department of Intensive Care Medicine, Hospital Curry Cabral, Centro Hospitalar Universitário de Lisboa Central, Lisboa, Portugal*

<sup>b</sup> *Department of Internal Medicine, Hospital de Santo António dos Capuchos, Centro Hospitalar Universitário de Lisboa Central, Lisboa, Portugal*

\* Corresponding author.

E-mail address: [tiagomisidoroduarte@gmail.com](mailto:tiagomisidoroduarte@gmail.com) (T. Isidoro Duarte).

<https://doi.org/10.1016/j.medin.2021.06.005>

0210-5691/ © 2021 Elsevier España, S.L.U. y SEMICYUC. All rights reserved.