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Article

Fluid Responsiveness Associates with Successful Weaning after Liver Transplant Surgery

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Abstract: A positive fluid balance may evolve to fluid overload and associate with organ dysfunctions, weaning difficulties, and increased mortality in ICU patients. We explored whether individualized fluid management, assessing fluid-responsiveness via passive leg-raising maneuver (PLR) before spontaneous breathing trial (SBT) associated with less extubation failure in ventilated patients with high fluid balance, admitted to the ICU after liver transplantation (LT). We recruited 15 LT patients in 2023. Postoperative fluid balance was +4476 [3697,5722] mL. PLRs were conducted at ICU admission (T1) and pre-SBT (T2). Cardiac index (CI) changes were recorded before and after SBT (T3). Seven patients were fluid responsive at T1, and 12 at T2. No significant differences occurred in hemodynamic, respiratory, and perfusion parameters between fluid-responsive and fluid-unresponsive patients at any time. Fluid-responsive patients at T1 and T2 increased their CI during SBT from 3.1 [2.8,3.7] to 3.7 [3.4,4.1] mL/min/m² (p= 0.045). All fluid-responsive patients at T2 were extubated after SBT and consolidated extubation. Two out of three of fluid-unresponsive patients experienced weaning difficulties. We concluded that fluid-responsive patients post-LT may start weaning earlier and achieve successful extubation despite high postoperative fluid balance. This highlights the profound impact of personalized assessment of cardiovascular state on critical surgical patients.

Keywords: fluid overload; fluid responsiveness; passive leg raising; spontaneous breathing trial

1. Introduction

Fluid balance, the net difference between intake and output, traditionally guides undifferentiated fluid management decisions in critically ill patients; however, fluid management in mechanically ventilated patients is complex. In general, positive fluid balance is associated with weaning challenges and adverse outcomes such as extubation failure and higher mortality rates [1,2]. According to a recent study, a one-liter surplus on day 3 in the ICU can elevate the mortality risk by 19%[3]. Conversely, negative fluid balance is associated with improved survival[1,4,5].

Nevertheless, even in the presence of fluid accumulation, some patients do not exhibit detrimental effects, which may be attributable to a condition known as fluid tolerance. This recently defined concept describes the degree to which a patient can tolerate fluid administration without causing organ dysfunction[6]. Thus, a positive fluid balance alone may not warrant reversal; its clinical impact is significant when associated with fluid overload, a condition that precedes organ dysfunction[5,7] and correlates with elevated morbidity and mortality[8–11]. Regrettably, most characterizations of fluid overload only define it arithmetically as a gain of 5-10% from admission weight without functional considerations[5,7]. Nevertheless, the pathophysiology of fluid overload is intricate and includes a net volume increase, redistribution of fluid from the peripheral to central

veins, diminished fluid elimination due to renal impairment, and endothelial dysfunction[12], all of which may result in organ failure.

This complexity underscores the need for personalized diagnostic approaches that not only quantify fluid balance but also assess the physiological impact on individual cardiovascular function. The classic paradigm of fluid management, primarily guided by aggregate metrics and standardized protocols, often overlooks nuanced physiological variances among individuals. In this context, passive leg raising (PLR) appears to be a helpful noninvasive strategy via the assessment of fluid responsiveness to bridge the gap between the theoretical understanding of the consequences of fluid overload and practical, personalized bedside decision-making regarding volume management. PLR is a simple and reversible maneuver that mimics rapid fluid loading by shifting venous blood from the legs towards the intrathoracic compartment, increasing ventricular preloads, and thereby, stroke volume and cardiac output[13]. A positive PLR maneuver is a strong indicator of fluid responsiveness in mechanically ventilated patients[13,14], revealing a ventricular systolic function operating along the plateau phase of the Frank-Starling curve[15].

A negative PLR maneuver, indicating fluid unresponsiveness, prompts the safe removal of excess fluid[16]; similarly, when performed before a spontaneous breathing trial (SBT) in nonsurgical patients[17], it is predictive of weaning failure of cardiac origin[18,19]. During the weaning phase, withdrawal of positive pressure increases venous return. Still, a state of fluid unresponsiveness can impede an appropriate increase in cardiac output[17,20,21], essential for matching the increased $\dot{V}O_2$ that occurs during the transition to spontaneous ventilation[20]. However, the predictive value of fluid responsiveness, assessed using PLR before weaning, has not yet been explored in surgical patients[17].

In the dynamic and critical setting of intensive care following liver transplant surgery, fluid balance management remains a cornerstone of patient care. These patients face critical fluid management challenges owing to their previously altered fluid homeostasis physiology[22] and surgery-induced fluid shifts, which increase the risk of post-transplant complications[22–25]. These facts make liver transplant patients a distinctively informative group for studying the predictive value of PLR, which could potentially guide more precise fluid therapy and improve the weaning process through fluid responsiveness determination.

This study aimed to explore whether fluid responsiveness, assessed using a PLR maneuver before a weaning trial, was associated with favorable ventilatory outcomes in a cohort of mechanically ventilated patients admitted to the ICU after liver transplantation, all of whom presented high postoperative fluid balance. We postulated that a personalized approach to fluid management considering cardiovascular responses using PLR could expedite the weaning process in these patients. In addition, such an approach could be helpful in critical care practice for postoperative patients undergoing great abdominal surgery.

2. Materials and Methods

We conducted a prospective observational study on postoperative liver transplant patients at an academic tertiary care center ICU in 2023. This was an ancillary study of the FLOW protocol (NCT04496583 registration in clinicaltrials.gov), and patients were recruited after obtaining approval from the Institutional Review Board. The study was exempt from informed consent owing to its observational nature, as approved by our Ethics Committee (ID 201015001-2021). The FLOW study was funded by FONDECYT grant N° 1200248-2020 from the Agencia Nacional de Investigación y Desarrollo (ANID), Chile.

Study Population

We recruited patients aged >18 years who were admitted to the ICU after liver transplantation for postoperative management. The exclusion criteria were acute postoperative, hemorrhagic, or vascular complications such as bleeding or hepatic artery or portal vein thrombosis. Patients were included when the research team was available (business days from 8:00 am to 12:00 pm). All patients had a central venous catheter and an arterial line at ICU entry.

Demographic and clinical profiles, along with standard ICU monitoring and fluid balance metrics, were systematically documented. In addition to fluid balance, we determined the estimated plasma volume (ePV) using the Strauss-derived[26] and precision-adjusted Duarte formula[27] to calculate the plasma volume status (PVS) using the Kaplan-Hakim formula[28]. PVS indicates the actual versus ideal plasma volume disparity calculated and was determined after ICU admission and before SBT for comparison with fluid balance and responsiveness status. The PVS offers a percentage-based evaluation of plasma volume that correlates well with plasma volume estimation when measured using a radio labeled albumin assay[26,29]. We used the suggested cut-off of 6.3% for this parameter[30].

Bioreactance Monitoring

We used a non-invasive bioreactance monitor (Cheetah-Starling SV©, Baxter. USA) because it provided continuous real-time data on cardiovascular function, inexistence of complications, and increased patient comfort, which is especially important in the postoperative setting. Bioreactance analyses the relative phase shift of an oscillating current passing through the thoracic cavity[31]. The device automatically recorded all data every 8 s to an exportable spreadsheet file.

Study Procedures

Hemodynamic Monitoring

After recruitment, a bioreactance-monitoring device was placed on each patient. We recorded the cardiac index (CI), stroke volume index (SVI), stroke volume variation (SVV), and thoracic fluid content (TFC) as the main hemodynamic variables. We assessed the absolute and relative positional variations in hemodynamic measures across baseline and passive leg raise at T1 and T2, as well as before and after SBT, in addition to the monitor's automated data output. The default 10% fluid responsiveness threshold of the device was utilized. A dual-investigator review of patient charts ensured a detailed capture of the impact of the PLR maneuver on hemodynamic parameters.

Spontaneous Breathing Trial

After the patient's condition stabilized following liver transplant surgery, sedation was withdrawn, and the process of gradually reducing mechanical ventilation support was initiated to transition from controlled to spontaneous ventilation. A protocolized weaning program was implemented to prepare patients for extubation, which involved assessing hemodynamic stability, peripheral perfusion, and neurological function, including consciousness and cough reflex. Once patients could tolerate a reduced applied airway pressure support of 10 cmH₂O, SBT was conducted for 30 min using a standardized protocol that included inspiratory pressure augmentation of 7 cm H₂O and zero positive end-expiratory pressure. No SBTs were performed using the T-piece.

Upon successful completion of SBT, the patient was extubated if deemed eligible by the attending physician. The patient was monitored for 48 h to ensure that reintubation was not required, and the maintenance of spontaneous ventilation by day 7 was considered consolidated extubation. A standardized post-extubation respiratory support protocol, including an oxygen mask, a high-flow nasal cannula (HFNC), and non-invasive ventilation, was available if needed. The respiratory therapy team managed the entire weaning process, which provided airway secretion clearance, bronchodilators, or other necessary interventions under physician supervision. Additionally, a post-extubation swallowing screening assessment was performed on all patients.

Passive Leg Raising

Stable data for the baseline SVI were obtained after 3 min in a semi-recumbent position at 45°. The first PLR maneuver (T1) was initiated by placing the patient in the supine position with the motorized ICU bed system and simultaneously raising the legs to 45° by two operators. The legs were secured using a rigid-cushioned frame. The results were automatically displayed on the screen 3 min

after starting the test. After 6 minutes, the patient was returned to the previous position. A second PLR maneuver was performed before SBT, as described for the first maneuver (T2). Before each PLR maneuver, the patients were informed of the test to avoid stressful triggers that could hinder the results. In addition, the same hemodynamic parameters were recorded before and after SBT (T3), at least 10-min lapse after T2 (Figure 1). At all times, attending physicians were unaware of the fluid responsiveness state.

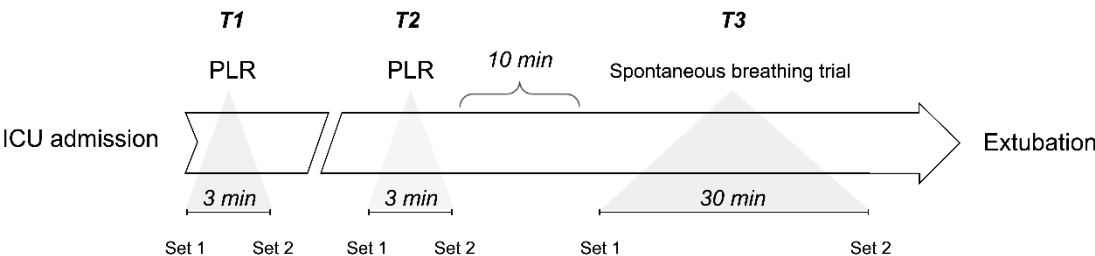


Figure 1. Timeline of three key cardiovascular monitoring time points in postoperative liver transplant patients since their ICU-entry. T1 corresponds to the first PLR maneuver, T2 to the second one (before spontaneous breathing trial) and T3 corresponds to the 30-min period between the start and conclusion of SBT. The set of hemodynamic parameters recorded for comparative analyses included CI, SVI, SVV, CVP, and TFC (see main text for details).

Statistical Methods

The study participants’ baseline demographic and general hemodynamic parameters are presented as median and 25-75 interquartile ranges (IQR 25,75) and proportions. Comparisons between fluid-responsive and fluid-unresponsive patients were performed using the Wilcoxon rank-sum test for continuous variables, owing to the nonparametric distribution of data. Multiple linear regression analyses were performed to examine the influence of MELD score, fluid responsiveness status, fluid balance, and CI on time to SBT and time to extubation. The significance level was set at $p < 0.05$. Data analysis and graphical representation were performed using the DATAtab Online Statistics Calculator (DATAtab e.U. Graz, Austria. <https://datatab.net>).

3. Results

Fifteen patients were recruited (general characteristics: Table 1; patient flow: Figure 2). At ICU admission, all patients presented with weight increase (9.3 [8.4,10.5] kg since hospital admission, 15% increase), high fluid balance (4480 [3698,5723] mL), and high PVS (13 [8,17] %).

Table 1. Baseline characteristics of patients after liver transplantation at ICU admission.

Variable	Value
Demographics	n = 15
Age (years)	62 [54,65]
Sex (female)	53%
Height (cm)	165 [158,173]
Weight (kg)	74 [56,75]
Body mass index	25 [21,26]
Clinical condition at admission	
APACHE II	14 [10,18]
MELD	21 [14,23]
SOFA	6 [6,10]
Norepinephrine (mcg/kg/min) (6 pts)	0.004 [0.000,0.220]

Fluid balance (m/L)	4480 [3697,5723]
Laboratory	
Lactate (mmol/L)	3.2 [1.7,5.1]
Hemoglobin (g/dL)	9.7 [8.6,10.5]
Albumin (g/dL)	3.4 [2.7,4.2]
Na (mEq/L)	142 (138,143]
K (mEq/L)	4.3 [3.9,4.4]
BUN (mg/dL)	20 [13,26]
Creatinine (mg/dL)	0.9 [0.7,1.2]

APACHE II Acute Physiology and Chronic Health disease Classification System II, MELD model for end-stage liver disease, SOFA Sequential organ failure assessment, BUN blood urea nitrogen, SBT spontaneous breathing trial.

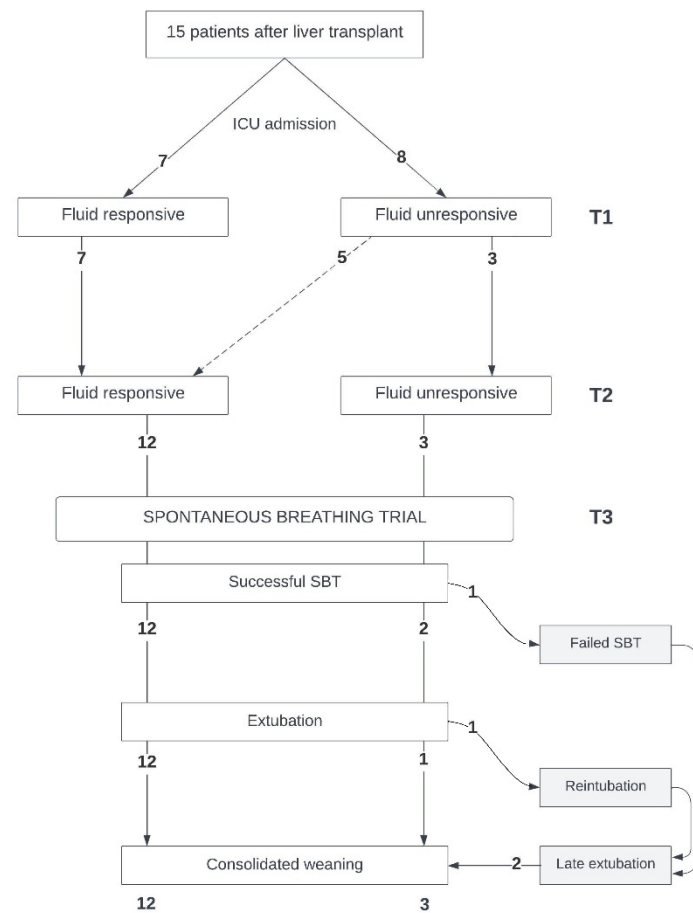


Figure 2. Flowchart describing the ventilatory outcomes of fifteen liver transplant patients after ICU admission, based on their fluid responsiveness and progression through a spontaneous breathing trial. Consolidated weaning was defined as no reintubation up to day 7 after extubation.

At ICU admission, seven patients were fluid-responsive, whereas eight were fluid-unresponsive. At T2, of the eight initially fluid-unresponsive patients, five became fluid-responsive (Figure 2). General hemodynamic and respiratory parameters were similar in fluid-responsive and fluid-unresponsive patients at T1 and T2, and maintained similar values during SBT (T3) (Table 2A). Heart rate was comparable between fluid-responsive and fluid-unresponsive patients at T1 and T2, and continued alike during SBT (Table 2B). Fluid-responsive patients started SBT earlier 14 [12,27] hours versus 35.5 [20;112] hours; $p = 0.06$) and achieved successful extubation sooner (20 [15;40] hours versus 45 [42;121] hours; $p = 0.045$) than their fluid-unresponsive counterparts. All fluid-responsive patients at T2 passed the SBT successfully and were extubated without complications. Conversely,

two of the three fluid-unresponsive patients at T1 who remained in that state until SBT had weaning problems: one failed SBT, and the other had to be reintubated (Figure 2). The SVI increased significantly in fluid-responsive patients at T1 and T2, unlike in fluid-unresponsive patients (Table 2B, Figure 3). During SBT, significant increases in CI and SVI were observed in patients previously identified as fluid-responsive at T1 and T2. There were no statistically significant changes in CVP, SvO2, pCO2, dCO2, or TFC in any group at T1, T2, or T3.

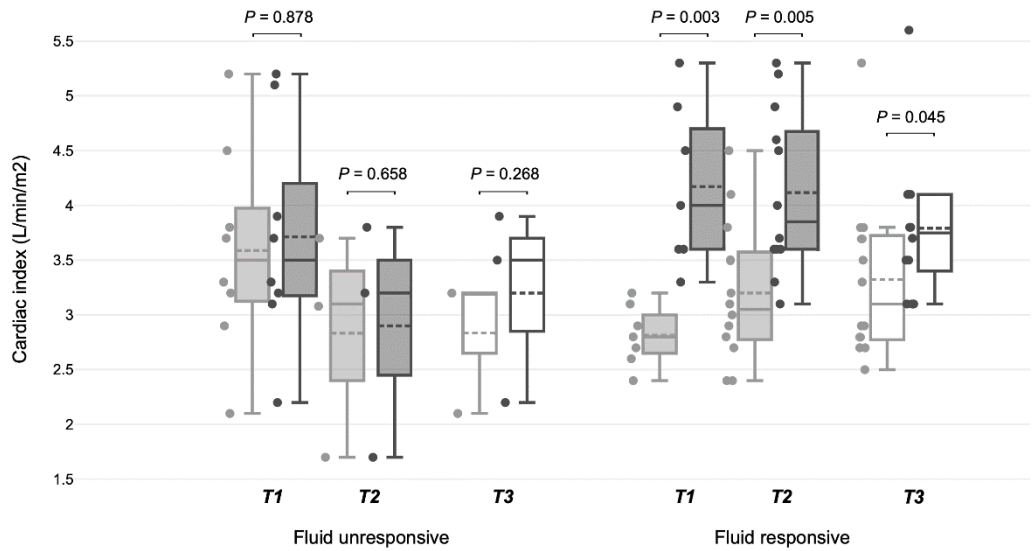


Figure 3. Cardiac index variations across different time points in fluid-responsive and fluid-unresponsive post-surgical liver transplant mechanically ventilated patients. T1: PLR maneuver at ICU-entry, T2: PLR before spontaneous breathing trial, T3: 30-min period between start and conclusion of before spontaneous breathing trial.

Table 2. (a). Macrohemodynamic and oxygenation changes during PLR maneuver at ICU admission (T1), PLR maneuver before SBT (T2), and before and after the spontaneous breathing trial (T3), according to fluid responsiveness status. **(b).** Cardiovascular parameter changes during PLR maneuver at ICU admission (T1), PLR maneuver before SBT (T2), and before and after the spontaneous breathing trial (T3), according to fluid responsiveness status.

(a)													
FLUID RESPONSIVE													
	HR	p	SAP	p	DAP	p	MA	p	RR	p	SaO ₂	p	pCO ₂
	(lpm)		(mm Hg)		(mm Hg)		(mm Hg)		(bpm)		(%)		(mm Hg)
PLR start (T1)	77	0.	115	0.4	47	0.0	94	0.2	20	0.2	100	0.2	
	[70, 85]	9	[108, 123]	36	[47, 60]	75	[90, 99]	80	[17, 21]	18	[99, 100]	32	
PLR end (T1)	77	1	120		65		103		20		98		
	[72, 85]		[105, 152]		[52, 72]		[90, 103]		[15, 21]		[96, 100]		

PLR	79	0.	112	0.5	55	0.0	92	0.5	22	0.1	100	0.9		
start	[69,	8	[104,	51	[47,6	54	[85,1	14	[18,	43	[98,10	12		
(T2)	88]	8	123]		5]		04]		22]		0]			
PLR	78	7	115		68		100		18		99			
end	[67,		[108,		[57,7		[84,1		[16,		[96,10			
(T2)	85]		130]		0]		15]		21]		0]			
SBT	80	0.	114	0.9	52	0.2	73	0.3	20	0.1	98	0.4	41	0.
start	[69,	9	[104,	08	[49,6	19	[68,8	19	[19,	98	[96,10	13	[37,4	1
(T3)	90]	3	132]		7]		5]		22]		0]		5]	9
SBT	75	2	116		62		78		18		97		37	5
end	[70,		[103,		[53,7		[73,8		[14,		[96,98		[33,3	
(T3)	91]		130]		0]		8]		21]		]		9]	

FLUID
UNRESPO
NSIVE

	HR	<i>p</i>	SAP	<i>p</i>	DAP	<i>p</i>	MA	<i>p</i>	RR	<i>p</i>	SaO ₂	<i>p</i>	pCO ₂	<i>p</i>
	(lp m)		(mm Hg)		(mm Hg)		P (mm Hg)		(bp m)		(%)		2 (mm Hg)	
PLR	71	0.	119	0.1	64	0.2	99	0.4	21	0.2	99	0.2		
start	[67,	5	[104,	89	[59,6	06	[85,1	01	[18,	44	[98,10	79		
(T1)	77]	2	142]		6]		16]		22]		0]			
PLR	73	7	136		68		111		16		98			
end	[61,		[114,		[64,7		[94,1		[13,		[96,99			
(T1)	78]		151]		3]		27]		19]		]			
PLR	76	0.	120	0.0	62	0.1	105	0.1	16	0.6	100	0.6		
start	[72,	2	[115,	50	[61,6	27	[99,1	27	[14,	58	[98,10	09		
(T2)	76]	6	132]		7]		16]		19]		0]			
PLR	74	8	150		81		128		18		99			
end	[67,		[149,		[74,8		[127,		[17,		[94,10			
(T2)	75]		158]		2]		137]		20]		0]			
SBT	70	0.	123	0.2	59	0.1	80	0.1	16	0.5	97	0.8	39	0.
start	[67,	8	[119,	75	[57,6	21	[80,9	84	[14,	13	[96,98	22	[38,4	2
(T3)	73]	2	146]		7]		3]		19]		]		3]	0
SBT	71	7	149		77		106		15		97		37	2
end	[66,		[148,		[75,7		[105,		[11,		[97,98		[33,3	
(T3)	74]		165]		7]		112]		18]		]		9]	

(b)													
FLUID RESPONSI VE													
		CI		SVI		SV		CVP		SvO		TFC	
		(L/mi	<i>p</i>	(mL/	<i>p</i>	V	<i>p</i>	(mm	<i>p</i>	²	<i>p</i>	(1/ Ω)	<i>p</i>
		n/m²)		m²)		(%)		Hg)		(%)			
PLR (T1)	start	2.8		37		21		9		74		110	
		[2.7,3.		[33,4		[15,		[8,10		[73,		[78,12	
		0]	0.0	3]	0.0	22]	0.0	]	0.5	74]	0.9	0]	0.9
PLR (T1)	end	4.0	03	55	05	13	35	9	29	73	71	113	12
		[3.6,4.		[49,5		[13,		[8,10		[68,		[75,11	
		7]		5]		16]		]		75]		6]	
PLR (T2)	start	3.1		40		16		9		74		94	
		[2.8,3.		[38,4		[14,		[8,10		[70,		[72,11	
		6]	0.0	4]	0.0	21]	0.0	]	0.6	75]	0.8	5]	0.0
PLR (T2)	end	3.9	05	53	01	13	39	9	81	71	76	99	59
		[3.6,4.		[45,5		[13,		[7,9]		[70,		[75,11	
		7]		5]		15]				73]		3]	
SBT (T3)	start	3.1		42		14		10		72		89	
		[2.8,3.		[32,4		[12,		[9,12		[70,		[72,11	
		7]	0.0	8]	0.0	18]	0.7	]	0.2	75]	0.0	6]	0.7
SBT (T3)	end	3.7	45	53	24	15	13	9	66	69	6	92	55
		[3.4,4.		[46,5		[12,		[7,10		[66,		[74,11	
		1]		6]		16]		]		71]		4]	
FLUID UNRESPO NSIVE													
		CI		SVI		SV		CVP		SvO		TFC	
		(L/mi	<i>p</i>	(mL/	<i>p</i>	V	<i>p</i>	(mm	<i>p</i>	²	<i>p</i>	(1/ Ω)	<i>p</i>
		n/m²)		m²)		(%)		Hg)		(%)			
PLR (T1)	start	3.5		47		14		9		71		66	
		[3.1,4.		[43,5		[8,1		[8,11		[69,		[55,84	
		0]	0.8	1]	0.5	6]	0.7	]	0.6	74]	0.6	]	0.9
PLR (T1)	end	3.5	78	50	74	13	21	9	45	74	28	66	94
		[3.1,4.		[46,5		[9,1		[5,12		[70,		[56,87	
		2]		3]		4]		]		74]		]	

PLR (T2)	start	3.1 [2.4,3.4]	0.6	41 [35,45]	0.5	15 [24]	0.5	9 [8,10]	0.1	71 [70,73]	0.7	69 [60,71]	0.9
	end	3.2 [2.5,3.5]	58	43 [36,47]	13	13 [12,23]	44	8 [7,9]	05	70 [69,72]	84	69 [58,72]	18
SBT (T3)	start	3.2 [2.7,3.2]	0.2	42 [38,44]	0.2	16 [19]	0.8	9 [8,11]	0.9	77 [76,78]	0.0	51 [50,58]	0.5
	end	3.5 [2.9,3.7]	68	49 [43,50]	75	14 [19]	27	9 [8,11]	93	72 [72,73]	5	52 [51,58]	13

PLR passive leg-raising maneuver, SBT spontaneous breathing trial, SVV stroke volume variation, CVP central venous pressure, SvO₂ central venous oxygen saturation, dCO₂ venous-to-arterial pCO₂ difference, TFC thoracic fluid content. HR heart rate, SAP systolic blood pressure, DAP diastolic blood pressure, MAP mean arterial pressure, RR respiratory rate, SaO₂ arterial oxygen saturation, pCO₂ arterial CO₂ partial pressure.

Fluid balance and PVS were similar between the fluid-responsive and fluid-unresponsive patients at T1 and T2 (Table 3A-B). Fluid balance and PVS were not associated with fluid responsiveness at T1 or T2 (Table 3A-B).

Table 3. (a) Fluid balance in postoperative liver transplant patients according to fluid responsiveness status. **(b)** Plasma volume status in postoperative liver transplant patients according to fluid responsiveness status.

(a)				
	Fluid balance (postoperative) (mL)	<i>p</i>	Fluid balance (before SBT) (mL)	<i>p</i>
Fluid responsive	5230 [3698,5723]	0.674	4476 [3697,5722]	0.281
Fluid unresponsive	4167 [3755,5583]		2997 [- 146,5747]	
(b)				
	Plasma volume status (postoperative) (%)	<i>p</i>	Plasma volume status (before SBT) (%)	<i>p</i>
Fluid responsive	17 [14,22]	0.156	17 [10,20]	0.226

Fluid unresponsive	9 [5,13]	8 [3,14]
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In the case of PLR maneuvers, Set 1 corresponds to baseline parameters and Set 2 for parameters at the end of the test. In the case of SBT, Set 1 corresponds to the hemodynamic parameters recorded for comparative analyses included CI, SVI, SVV, CVP, and TFC (see main text for details) before starting SBT and Set 2 to the recording of the same parameters at the end of the trial.

4. Discussion

The findings of our observational study, albeit small-scale, highlight the profound impact that personalized fluid management may have on post-liver transplant recovery. Our data suggest that identifying the condition of fluid responsiveness after surgery is potentially beneficial for achieving earlier weaning and successful extubation, independent of fluid balance. Notably, we observed that a high fluid balance was not equivalent to a fluid unresponsiveness state. Fluid responsiveness, assessed using PLR maneuvers, delineates a subgroup of patients who significantly benefit from tailored fluid management strategies, manifesting in more successful weaning and extubation outcomes. This correlation not only proposes fluid responsiveness as a critical determinant of patient-specific care but also underscores the limitations of conventional, one-size-fits-all fluid management and removal protocols.

All patients who emerged fluid-responsive after liver transplant surgery maintained this state. This differs from other ICU contexts, such as sepsis, where fluid responsiveness is inconstant [32,33]. In our patients, the tendency towards early fluid responsiveness post-transplantation may suggest a subset of individuals better adapted from a cardiovascular perspective to significant surgical stress, hence displaying readiness for weaning. These patients can adequately accommodate the intrathoracic positive pressure loss inherent to an SBT, the concurrent increase in venous return, and, owing to their fluid-responsiveness state, respond to increasing their cardiac index, allowing for an uncomplicated extubation. Conversely, fluid-responsiveness assessment by performing a PLR maneuver may serve as a precautionary measure for fluid-unresponsive patients post-surgery, signaling a need for fluid removal that can be performed without risking hemodynamic stability [14,34].

It is crucial to recognize that the measured post-surgery fluid balance, often an imprecise estimate [35], could reflect less critical conditions such as fluid redistribution or capillary leak syndrome, which do not necessarily induce cardiac or other organs’ dysfunction. Therefore, our findings support the consideration of fluid responsiveness over immediate fluid balance correction during the weaning process of postoperative liver transplant patients. In any case, the potential benefit of transitioning patients from fluid unresponsiveness to responsiveness before weaning warrants further investigation.

Our insights provide a re-evaluation of clinical practice, advocating for integrating simple, personalized management strategies into standard care protocols. While our findings may contribute to the evidence on PLR utility in post-surgical settings, they are yet to be robustly validated. Our results propose an expanded application of PLR for predicting cardiovascular and respiratory responses to SBT among pre-weaning surgical patients, an area previously unreported [17].

Our study was limited by its small size, single-center setting, potential assessment bias owing to device technology, unblinded fluid management from the attending physicians, and its observational nature. Therefore, these insights should be interpreted as provisional and call for further research to ascertain the predictive value of PLR in broader surgical critical care scenarios.

5. Conclusions

Our preliminary observations suggest that, irrespective of postoperative fluid balance, patients demonstrating fluid responsiveness post-liver transplantation may start weaning earlier and achieve successful extubation. This underscores the potential prognostic value of fluid responsiveness as an

indicator of sufficient cardiovascular adaptation for weaning in surgical patients and highlights the profound impact of personalized fluid assessment and management on critical surgical care patient recovery.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Table S1

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Informed Consent Statement: Patient consent was waived due to its observational nature as approved by the Ethics Committee of Pontificia Universidad Católica de Chile.

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