

Goal-directed fluid optimization using plethysmography variability index in laparoscopic bariatric obese patients: is it the answer?

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Objective

The aim of the study was to compare effect of goal-directed fluid replacement using plethysmography variability index (PVI) guidance versus liberal fluid regimen in elective laparoscopic bariatric surgery on pulmonary oxygenation and gastrointestinal, cerebral, and renal function.

Materials and methods

This randomized-controlled trial included 60 consecutive patients who were 20–40 years of age with BMI greater than 40 scheduled for elective laparoscopic bariatric surgery between June 2010 and December 2011. Patients were randomized into 'liberal fluid' (LF) or 'goal-directed' (GD) fluid infusion group. All patients received 500 ml lactated Ringer's solution then 1–2 ml/kg/h in the GD group or 6–8 ml/kg/h in the LF group. A 5-min bolus infusion of 200 ml of 6% hydroxyl ethyl starch was administered, if PVI goes above 14, urine output less than 0.5 ml/kg/h, heart rate greater than 100/min, or decreased systolic blood pressure less than 20% of baseline value. This colloid bolus was repeated until 20 ml/kg is reached then lactated Ringer's solution was used for further boluses. The primary outcome measures were length of hospital stay, postoperative hypoxemia assessed by PO_2/FiO_2 ratio, and serum lactate level.

Results

Intraoperatively, lactate level and volumes of infused Ringer's lactate and hydroxyl ethyl starch were significantly lower in the GD group ($P < 0.001$). PVI was significantly higher in the GD group ($P < 0.001$). Intraoperatively, lactate level and urine output were significantly lower in the GD group ($P < 0.001$). Postoperatively, the GD group showed significantly lower urine output ($P < 0.001$) and shorter time to recovery ($P < 0.001$) to first bowel movement ($P < 0.001$) and to resume normal diet ($P < 0.001$). Hypoxemia, diuresis, and fatigue were significantly more frequent in the LF group. No significant difference was seen in other postoperative complications.

Conclusion

Goal-directed, PVI-guided intraoperative fluid replacement significantly improved clinical outcome compared with liberal fluid intake. PVI guidance provides a sensitive and accurate determinant of fluid responsiveness and allowed for lower fluid intake. We recommend GD intraoperative fluid replacement with PVI and arterial blood gases (ABG) guidance in morbidly obese patients undergoing laparoscopic bariatric surgery.

Keywords:

bariatric, goal directed, lactate, liberal, plethysmography variability index

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Introduction

Perioperative fluid administration is an integral part for almost any surgical procedure, and consequently is an everyday issue for most anesthesiologists. In recent years, several studies have shown renewed interest in perioperative fluid therapy demonstrating that different fluid therapy regimens can influence the postoperative outcome. In morbidly obese patients, perioperative fluid therapy has double-edged implications. In normal weight individuals, it has been shown that, during minor or medium-sized procedures, liberal intraoperative fluid administration improves perioperative physiologic organ function and patient recovery and reduces hospital stay [1]. Nevertheless, in obese patients, this may lead

to hypertension, pulmonary edema, and increased requirement for ventilatory support. In contrast, fluid restriction may result in acute tubular necrosis and organ dysfunction [2].

To avoid deleterious effects of volume expansion, preload dependence assessment is crucial to guide fluid therapy. Thus, the principle goal is optimizing cardiac preload. Measuring volume responsiveness, occasionally referred to as 'goal-directed' approach, seems to be an interesting alternative to direct fluid replacement protocols [3].

As static parameters of measuring cardiac preload, such as central venous pressure and pulmonary

artery wedge pressure [4], have been shown to be of little help in decisions regarding fluid replacement, dynamic parameters relying on respiratory variations in stroke volume have been recently shown to be better indicators of fluid responsiveness [5].

Plethysmography variability index (PVI) is an algorithm that measures the respiratory variability of the pulse amplitude in fingertip transmission plethysmography, and thus has the ability to predict fluid responsiveness and guide fluid management [6]. PVI has been incorporated in our study to guide goal-directed fluid regimen hoping to improve postoperative outcome.

The purpose of this randomized-controlled trial was to compare goal-directed, using PVI guidance, versus liberal fluid replacement regimens in bariatric patients undergoing elective laparoscopic surgery regarding their effects on pulmonary oxygenation, resuming bowel movement, cerebral function recovery, and diuresis.

Materials and methods

After local hospital Ethical Committee approval and obtaining written informed consent from the patients, 60 consecutive patients ASA II and III with age range 20–40 years and BMI greater than 40 scheduled for elective laparoscopic bariatric surgery during the period from June 2010 to December 2011 were enrolled in this randomized-controlled trial.

Exclusion criteria were history of uncompensated cardiac disease (including arrhythmias), respiratory disease, renal dysfunction (creatinine > 50% of upper limit of normal value), or significant liver dysfunction (liver enzymes > 50% of upper limit of normal value).

Preoperative fluid status was standardized in all patients by ensuring that all patients were fasting since midnight before the operation and drank 200 ml of water at 6:00 a.m. on the morning of surgery and that all surgeries were performed in the morning.

All patients were premedicated with oral ranitidine and oral midazolam (3 mg), 2 h preoperatively. Upon arrival to the operating room, patients were randomized by the sealed envelope procedure to either 'liberal' (LF) or 'goal-directed' (GD) fluid infusion group. The randomization code was not known to the investigators until the end of the study.

Egg crate padding was placed under the knees and below the heels of the patients so as to create a degree of flexion. Pneumatic compression device consisting of a compressor and an inflatable cuff covering the

entire leg was applied to help preventing deep venous thrombosis formation.

Following preoxygenation, anesthesia was induced with propofol (200–350 mg) intravenously (2–4 mg/kg) and fentanyl (2 µg/kg) and was maintained with isoflurane. Rocuronium (0.4–0.6 mg/kg) was used to facilitate endotracheal intubation and increments were used to maintain neuromuscular block throughout surgery. Ventilation was adjusted to an end tidal CO₂ of 35–40 mmHg, with a tidal volume of 13–15 ml/kg ideal body weight. Heart rate, noninvasive and invasive arterial blood pressure using 22-G arterial radial cannula, oxygen saturation, capnography, inhaled gas concentration, and temperature were continuously measured in all patients using Dräger infinity vista XL. Normothermia throughout the operation was maintained with a Bair-Hugger (Augustine Medical, Eden Prairie, Minnesota, USA). Masimo Rainbow SET Pulse Co-Oximetry (Masimo NASDAQ; MASI, USA) readouts from an additional fingertip sensor were measured every 2.5 min.

The fluids were administered and controlled by an anesthetist not involved in patient assessment. Patients assigned to the GD fluid group received 500 ml crystalloid lactated Ringer's solution then 1–2 ml/kg/h, whereas the LF group received 500 ml crystalloid then 6–8 ml/kg/h. An additional 5-min bolus infusion of 200 ml colloid 6% hydroxyl ethyl starch was administered if one or more of the following criteria occur: PVI rising above 14, urine output less than 0.5 ml/kg/h, heart rate greater than 100/min, or decreased systolic blood pressure more than 20% of baseline values. This colloid bolus was repeated until 20 ml/kg is reached then lactated Ringer's solution was used for further boluses. At the end of surgery, arterial blood samples were taken; the lactate concentration was measured using an ABL 620 analyzer (Radiometer, Copenhagen, Denmark); and venous blood sample was taken to measure serum creatinine concentrations.

At the end of surgery, all patients received 8 mg ondansetron and 30 mg ketorolac. In the postanesthesia care unit (the surgical ward personnel were unaware of group assignment and were not part of investigator team), the Aldrete score was measured (Table 1). This score is designed to assess the patients' transition from phase I recovery to phase II recovery, from discontinuation of anesthesia until return of protective reflexes and motor function, and time to recovery. The total score is 10. Patients scoring at least 8 and/or who are returned to similar preoperative status are considered fit for transition to phase II recovery; hence, time to recovery is recorded. The postoperative morbidity was recorded; overnight pulse oximetry is used to establish patient's

night-time arterial oxygen saturation. Occurrence of fatigue was measured on 10-point fatigue scale: 1 = no fatigue and 10 = worst fatigue imaginable after surgery; urine output, time to first bowel movement, and time to resume normal diet were recorded.

The primary outcome measures were postoperative hypoxemia and serum lactate level. Postoperative hypoxemia was assessed by the arterial oxygen tension/fractional inspired oxygen ratio (PO_2/FiO_2), a widely used oxygenation index. A ratio above 300 is indicative of adequate ventilation, below which patients usually require ventilatory assistance in the form of continuous positive airway pressure (CPAP). The secondary outcome measures were hemodynamics (heart rate, invasive blood pressure), gastrointestinal signs (nausea, vomiting, time to regain intestinal movement, postoperative ileus), cerebral function recovery (drowsiness), serum creatinine, diuresis, and rhabdomyolysis.

Statistical analysis

Data were analyzed using IBM SPSS Advanced Statistics version 20.0 (SPSS Inc., Chicago, Illinois, USA). Numerical data were expressed as mean and SD. Qualitative data were expressed as frequency and percentage. The χ^2 -test (Fisher's exact test) was used to examine the relationship between qualitative variables. For quantitative data, comparison between two groups was performed using independent sample *t*-test. A *P*-value less than 0.05 was considered significant.

Results

The two studied groups were comparable in age and BMI. There were no significant differences between the two groups regarding duration of anesthesia and surgery and initial baseline systolic blood pressure. There was statistically significant difference between the two groups regarding heart rate ($P = 0.005$); however, the values were within the clinically accepted range. There was no significant difference between the two groups regarding frequency of associated morbidity (Table 2).

Intraoperatively (Table 3), lactate level was significantly lower in the GD group ($P < 0.001$). The LF group received significantly higher volumes of lactates and hydroxyl ethyl starch ($P < 0.001$). PVI was significantly higher in the GD group ($P < 0.001$). There was no significant difference between the groups in peak airway pressure ($P = 0.133$). Urine output was significantly lower in the GD group ($P < 0.001$).

Postoperatively, the GD group showed significantly lower urine output ($P < 0.001$) and shorter time to recovery ($P < 0.001$) of first bowel movement ($P < 0.001$) and time to resume normal diet ($P < 0.001$).

Table 1 Aldrete score

Scores	2	1	0
Respiration	Able to take deep breath and cough	Dyspnea/shallow breathing	Apnea
O ₂ saturation	Maintains >92% on room air	Needs O ₂ inhalation to maintain O ₂ saturation >90%	Saturation <90% even with supplemental O ₂
Consciousness	Fully awake	Arousable on calling	Not responding
Circulation	BP \pm 20 mmHg preoperative	BP \pm 20–50 mmHg preoperative	BP \pm 50 mmHg preoperative
Activity	Able to move 4 extremities	Able to move 2 extremities	Able to move 0 extremities

BP, blood pressure.

Table 2 Demographic and baseline clinical and laboratory data of the two studied groups

Demographic data	LF group (n = 30)	GD group (n = 30)	<i>P</i> -value
Age (years)	38.1 \pm 5.5	36.4 \pm 6.2	0.265
Sex (M/F)	16/14	12/18	0.301
BMI (kg/m ²)	40.6 \pm 4.9	39.5 \pm 5.4	0.414
Duration of anesthesia (min)	147.8 \pm 12.1	141.5 \pm 19.2	0.134
Duration of surgery (min)	127.4 \pm 18.7	119.8 \pm 22.2	0.157
Systolic blood pressure (mmHg)	135.0 \pm 18.0	132.6 \pm 17.8	0.615
Heart rate (beats/min)	91.0 \pm 10.3	99.4 \pm 12.1	0.005
SpO ₂ (%)	96.5 \pm 2.0	96.2 \pm 2.1	0.617
PO ₂ /FiO ₂ ratio	391 \pm 68	386 \pm 73	0.785
Hypertension [<i>n</i> (%)]	9 (30.0)	11 (36.7)	0.584
Preoperative DM [<i>n</i> (%)]	10 (33.3)	8 (26.7)	0.573

DM, diabetes mellitus; GD, goal-directed; LF, liberal fluid; SpO₂, oxygen saturation.

Table 3 Intraoperative criteria of the two studied groups

Intra operative data	LF group (n = 30)	GD group (n = 30)	<i>P</i> -value
Lactate level (mmol/l)	1.41 \pm 0.40	0.86 \pm 0.15	<0.001
Intraoperative ringer's lactate (ml)	2236 \pm 221	1407 \pm 27	<0.001
Intraoperative hestril (ml)	464 \pm 89	250 \pm 0	<0.001
Plethysmography variability index	13.3 \pm 0.8	15.5 \pm 1.4	<0.001
Peak airway pressure (cmH ₂ O)	37.1 \pm 2.8	36.1 \pm 2.3	0.133
Urine output (ml)	210 \pm 32	165 \pm 25	<0.001

Data are represented as mean \pm SD; GD, goal-directed; LF, liberal fluid.

Hypoxemia ($PO_2/FiO_2 > 300$) was significantly more frequent in the LF group ($P = 0.007$), so was fatigue ($P = 0.020$). Diuresis was more frequent in the LF group ($P = 0.009$). There was no significant difference in other postoperative complications (Table 4).

Discussion

We found an improved outcome in recovery parameters in the GD group in comparison with the LF intake

Table 4 Postoperative criteria of the two studied groups

Postoperative data	LF group (n = 30)	GD group (n = 30)	P-value
Urine output (mean ± SD) (ml)	2110 ± 106	1930 ± 95	<0.001
Time to first bowel movement (mean ± SD) (h)	22.0 ± 1.5	11.5 ± 2.3	<0.001
Time to resume normal diet (mean ± SD) (h)	31.4 ± 4.6	20.6 ± 6.5	<0.001
Time to recovery (mean ± SD) (min)	95 ± 32	45 ± 8	<0.001
Systolic blood pressure (mean ± SD) (mmHg)	142 ± 15	120 ± 21	<0.001
Pulse (mean ± SD) (beats/min)	91 ± 11	93 ± 6	0.386
PO ₂ /FiO ₂ ratio	294 ± 23	332 ± 25	<0.001
PO ₂ /FiO ₂ ratio < 300 [n (%)]	12 (40)	3 (10)	0.007
Fatigue [n (%)]	19 (63.3)	10 (33.3)	0.020
Drowsiness [n (%)]	7 (23.3)	5 (16.7)	0.519
Postoperative morbidity [n (%)]			
Nocturnal hypoxemia	7 (23.3)	2 (6.7)	0.071
Hypotension	14 (46.7)	8 (26.7)	0.108
Diuresis	18 (60.0)	8 (26.7)	0.009
GI complications [n (%)]			
Nausea and vomiting	7 (23.3)	12 (40.0)	0.165
PO ileus	8 (26.7)	4 (13.3)	0.197
Length of hospital stay	3 (1–3)	2 (1–3)	0.687

Time to recovery = Aldrete score 8–10; GD, goal-directed; GI, gastrointestinal; LF, liberal fluid; PO, postoperative; *No P-value because number of cases in the two groups is small.

group. These parameters included cerebral recovery as presented by the significantly shorter time in the postoperative recovery room, significantly less time to first flatus passage, as well as diminished intraoperative lactate levels in the former group. Postoperative hypoxemia and diuresis were less frequent in the GD group.

With lack of standardization, available data cannot allow general evidence-based recommendations in procedure-specific perioperative management of fluids [7]. This is particularly true in morbid obesity. These patients are more liable to complications with inadequate or overinfusion. On one hand, fluid restriction in obese patients may lead to acute tubular necrosis and organ dysfunction [5]. Liberal fluid intake, on the other hand, poses a risk in the postoperative recovery and healing especially in obese patient [1]. Furthermore, in a systematic review of over 80 randomized clinical trials [7], recommended avoiding fluid overload in major surgical operations. Nisanevich *et al.* [8] presented higher infection rates and longer hospitalization periods in patients receiving liberal fluid intake [9].

There is a general concept advocating liberal fluid intake. It states that preoperatively patients are dehydrated, with an increased insensible perspiration with surgical incisions, and renal excretion can dispense with

fluid overload [10]. This cannot be applied to obese individuals as a rule. Hence, fluid optimization by goal-directed fluid administration in an attempt to reach the best target for such patients seems an attractive and promising alternative.

We found a statistically significant postoperative decline in PO₂/FiO₂ ratio in both groups. However, it reached below 300 in 40% of the LF group compared with 10% of the GD group ($P = 0.007$). PO₂/FiO₂ is a very important tool to assess proper tissue oxygenation. It over-rides the use of oximetry as was performed by other studies [11].

Liberal fluid administration studies have detected a propensity toward pulmonary congestion, leading to hypoxia [1]. In addition, invasive monitoring and postoperative ventilation correlated with the amounts of infused fluids in such patients as well as the postoperative weight gain [12]. This poses a higher need for postoperative oxygen therapy and ventilatory support. Adequate tissue perfusion and oxygenation is important for wound healing. In fact, risk for surgical wound infection is inversely proportional to tissue oxygenation [13].

We found less total need for intake of crystalloids and lower lactate levels in the goal-directed, PVI-guided approach when compared with the LF group. Serum lactate levels are an indirect and sensitive detector of intravascular fluid volume adequacy and tissue hypoxia. Furthermore, aggressive crystalloid infusion showed impeded oxygen consumption [14]. Similarly, Forget *et al.* [6] showed lower lactate levels and improved fluid management in major abdominal surgery patients performing PVI-guided fluid replacement. Functional parameters such as pulse pressure variation, PVI, and stroke volume variation, stroke volume variation (SVV), proved more sensitive and specific than cardiac filling pressures central venous pressure and pulmonary artery wedge pressure in fluid administration assessment. Cannesson *et al.* [15] showed that PVI significantly affected fluid responsiveness, with a cutoff more than 14% to detect responders from no responders. Recently, Hood and Wilson [16] showed a significant predictive value of fluid responsiveness of PVI when compared with the costly, more tedious, yet accurate endoscopic Doppler assessment method for stroke volume. Hence, PVI can provide a good noninvasive alternative detector of preload adequacy and proper intraoperative fluid management.

We found a statistically significant lower intraoperative urine output volume in the GD group. Nevertheless, this did not have any clinical significance in the total patient outcome or recovery parameters. Recently,

Matot *et al.* [17] challenged the popular concept that urinary output is of high significance intraoperatively. They showed urine output to be low, despite the use of high volume fluid therapy. Hence, urinary output should not have a significant impact on decisions in intraoperative fluid administration.

Conclusion and recommendations

Intraoperative fluid replacement in a goal-directed, PVI-guided manner significantly improved clinical outcome compared with liberal fluid intake. The former group showed lower lactate levels, better oxygenation and tissue perfusion, as well as improved cerebral and bowel recovery. PVI-guided technique provided a sensitive and accurate determinant of fluid responsiveness and allowed for lower fluid intake. Urine output, despite varying in volume, did not carry clinical significance in the outcome in either group. Hence, we recommend GD intraoperative fluid replacement with PVI and ABG guidance in morbidly obese patients undergoing laparoscopic bariatric surgery.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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