Morbid obesity and optimization of preoperative fluid therapy

Tomi Pösö [1], Doris Kesek [1 2], Roman Aroch [1], Ola Winsö [1]

[1] Department of Surgical and Perioperative Sciences, Umeå University, Umeå, Sweden
[2] Department of Cardiothoracic Anaesthesia, Heart Centre, Umeå University, Umeå, Sweden

Short title: Volume-challenge in morbid obesity

Corresponding author:

Tomi Pösö, Department of Surgical and Perioperative Science, Umeå University,
90185 Umeå, Sweden
Tel: +46 76 8397002; e-mail: tomi.poso@anestesi.umu.se; tomi.poso@telia.com

Abstract

Context: Preoperative venous return (VR) optimization and adequate blood volume is essential in management of morbidly obese patients (MO) in order to avoid perioperative circulatory instability. In this study, all subjects underwent a preoperative three-week preparation by rapid-weight-loss-diet (RWL) as part of their treatment program for bariatric surgery.

Design: Prospective, observational study.

Setting: Sunderby County Hospital, Luleå, Sweden.

Subjects: Thirty-four morbidly obese patients consecutively scheduled for bariatric surgery.

Interventions: Preoperative transthoracic echocardiography (TTE) was performed in the awake state before and after intravascular volume-challenge (VC) of 6 ml colloids/kg ideal body weight (IBW). Effects of standardized VC were evaluated by TTE. Dynamic and non-dynamic echocardiographic indices for VC were studied.

Main outcome measures: Volume-responsiveness and level of VR before and after VC were assessed by TTE. An increase of stroke volume (Δ SV) $\geq$ 13% was considered as a volume-responder.

Results: 29/34 patients were volume-responders. After VC, a majority of patients (23/34) were euvolemic, and only 2/34 were hypovolemic. Post VC hypervolemia was observed in 9/34 of patients.

Conclusions: The IBW-based volume challenge regimen was found to be suitable for preoperative rehydration of RWL-prepared MO. Most of the patients were volume-responders. Preoperative state of VR was not associated with volume-responsiveness. IBW-estimates and appropriate monitoring avoids potential hyperhydration in MO.

For VC assessment, conventional Doppler indices were found to be more suitable compared to tissue Doppler, giving sufficient information on pressure-volume correlation of the left ventricle in morbidly obese.

Key words: morbid obesity, preoperative volume-challenge, transthoracic echocardiography, TTE, rapid weight loss, bariatric surgery, diastolic function, rehydration; venous return

Abbreviation list

CG, control group
IBW, ideal body weight
MO, morbidly obese patients
NIBP, non-invasive blood pressure
RAP, right ventricular pressure
RYGB, Roux-en-Y gastric bypass
RWL, rapid-weight-loss diet
SV, stroke volume
ΔSV, change of stroke volume
TBW, total body weight
VC, volume-challenge
VR, venous return

Abbreviations for Echocardiography:
A4C, apical 4-chamber projection
A2C, apical 2-chamber projection
EF, ejection fraction
FS, fractional shortening
IVC, inferior vena cava
IVCCI, inferior vena cava collapsibility index
LV, left ventricle
LVEDA, left ventricular end-diastolic area
LVESA, left ventricular end-systolic area
LVOT, left ventricular outflow tract
LVOTd, left ventricular outflow tract diameter
PLAX, parasternal long axis projection
PW, pulsed-wave Doppler imaging
RV, right ventricle
SAX, parasternal short axis projection
TAPSE, tricuspidal annular plane systolic excursion
TDI, tissue Doppler imaging
TTE, transthoracic echocardiography

2

Introduction

The number of morbidly obese patients (MO) and bariatric surgery has increased dramatically in recent decades (1-4). Preoperative weight loss, including preparation by a rapid-weight-loss-diet (RWL), aims to facilitate laparoscopic bariatric surgery (5-7). However, RWL can expose MO to preoperative hypovolemia (8). In addition, cardiac involvement, including impaired relaxation and compliance of the left ventricle, is common in obesity of long duration (8-11). Hence, fluid administration in morbidly obese patients is challenging and requires caution throughout the perioperative course, in order to avoid excessive rehydration (12-14). Publications concerning fluid therapy regimes for patients with high BMI, especially with focus on preoperative management, are few, and are not based on general consensus (15-18). Preoperative risk assessment and optimization by TTE without bias caused by anaesthetics is addressed in patients with suspected cardiac disease (19).

The aim of this study was to evaluate preoperative effects of an individualized, ideal body weight (IBW) -based volume-challenge (VC) on hemodynamics, stroke volume and amount of venous return to the heart. In addition, dynamic and non-dynamic echocardiographic indices for VC were studied.

Methods

Ethical approval for this study (DNR 09-042M and 2012-439-32M) was provided by the Regional Ethical Review Board in Umeå, Sweden (Chairman Anders Iacobaeus). Informed consent was obtained from all included patients. In this single center prospective study, 34 RWL-prepared morbidly obese patients consecutively scheduled for elective bariatric surgery by laparoscopic Roux-en-Y gastric bypass were included. Patients with untreated hypertension, unstable angina pectoris, significant valve regurgitation or stenosis, and known severe pulmonary disease were excluded. In addition to a preoperative RWL-period of three weeks, all patients fasted at least 6 hours before surgery (nil per os). Patient co-morbidities, regular medication, characteristics on the day of surgery, and frequency of cardiopulmonary investigations in the last ten years were assessed preoperatively.

Protocol

All patients were studied in the awake state before induction of anesthesia. The patients were assessed twice in the supine position with transthoracic echocardiography (TTE) by an experienced clinical cardiac physiologist immediately prior to surgery. An identical comprehensive TTE-protocol was implemented before and 5 minutes after volume-challenge. Volume-challenge was given to all patients as a rapid i.v. infusion of colloid fluids (Volulyte™, Fresenius Kabi Ab, Sweden) 6 ml/ kg of the calculated ideal body weight. A rough approximation of ideal body weight was calculated as the height in cm minus 100 in both genders (10). No other i.v. fluids were given during the period when the TTE assessments were performed. Non-invasive blood pressure was measured just before and after volume-challenge in the supine position with a proper sized cuff.

Pre- and post-VC levels of venous return (preload) were categorized into hypovolemia, euvolemia or hypervolemia by converting inferior vena cava (IVC) diameters and IVC respiratory variation to estimations of right atrial pressures (RAP) according to current evidence (8, 20). Patients were classified as volume-responders if an increase in stroke volume ≥ 13 % after volume-challenge was measured. In addition, diastolic function of the left ventricle was assessed before and after volume-challenge (21, 22), as described below.

Protocol for transthoracic echocardiography

Echocardiographic data were collected with an ultrasound device (Sequoia-512, Acuson-Siemens, Mountain View, CA) and a multifrequency transducer (4V1c). Three consecutive end-expiratory cardiac cycles were collected; the mean values of these were used for later statistical comparisons. Off-line analysis of data was made in accordance with current guidelines (21, 23) with commercially available software (EchoPac, GE Healthcare, Horten, Norway). Scanning for possible significant valve pathologies was made by coloured and continuous Doppler and visual evaluation of valve morphology. In case of pathological findings in valves patients were excluded from the study.

2-D and M-Mode measurements

Standard acquisition windows for TTE were used including parasternal long axis (PLAX), short axis (SAX), apical 4-chamber (A4C) and subcostal projections. Apical 2 (A2C) and 3 chamber projections were used only for visual assessment of left ventricular (LV) contractility. Left ventricular end-diastolic (LVEDd) and end-systolic diameter (LVESd), end-diastolic wall thickness (septal and posterior walls) of LV and left atrium anterior-posterior diameter in end-systole (LAd) were measured from PLAX windows perpendicular to the ventricular long-axis by 2-D assuring an optimal measurement orientation. In order to minimize bias in stroke volume (SV) comparison, left ventricular outflow track diameter (LVOTd) was measured in PLAX windows by 2-D only before volume-challenge. Mean values of 3 separate LVOTd were used in SV calculation. Inferior vena cava diameters (IVC) and IVC respiratory variation (inferior vena cava collapsibility index, IVCCI) were measured from subcostal windows approximately 2 centimetres from the junction of the IVC and the right atrium, perpendicular to the IVC's long-axis.

Left ventricular systolic function was evaluated visually by left ventricle fractional shortening (% FS) and calculated ejection fraction in % (EF %) from SAX areas. Left ventricular end-diastolic (LVEDA) and end-systolic (LVESA) areas were traced in SAX windows at mid-chamber level. A conventional formula for EF % calculation was used: EF % = 100 % x (LVEDA – LVESA / LVEDA). Systolic function of the right ventricle (RV) was assessed visually and by M-mode collected tricuspid annular plane systolic excursion (TAPSE).

Conventional and tissue Doppler (TDI) measurements

Transmitral inflow and pulmonary venous inflow velocities were measured from 3 consecutive end-expiratory cardiac cycles with pulsed-wave Doppler (PW) from A4C windows. Mean values were used for calculation of conventional dynamic indices and for statistics. Velocity time integral of left ventricular outflow track (VTI_{LVOT}) was obtained with PW from apical 5 chamber windows (A5C). Mean values of VTI_{LVOT} were used for stroke volume calculation. Stroke volume of the left ventricle in ml was calculated by formula: $SV = 0.785 \times LVOTd^2 \times VTI_{LVOT}$. Tricuspid valve insufficiency was measured with continuous Doppler for calculation of a pressure gradient between the right ventricle and the right atrium (24). Tissue Doppler (TDI) velocities; systolic (Sm), E'- and A'- wave; were collected only from septal position of the mitral annulus due to useless TDI-quality in lateral position of the mitral annulus. The E/E' septum-ratio was calculated (21).

Evaluation of filling pressure dynamics in left ventricle

Evaluation of diastolic properties of LV was performed (21) using TDI, where the E/E' septum-ratio was used when available (expecting some dropout due to missing lateral registration in this cohort). Signs of possible pathological instability in filling pressures and decreased compliance of LV were collected and assessed (21, 22).

Statistical methods

Statistical Package for Social Sciences (SPSS) version 20.0 was used for data processing. Comparisons of mean values between pre- and post VC variables were performed by Student's t-test for independent variables, supposing unequal variances. Chi-2 and/or Fisher's Exact Tests were used for comparison of pre- and post-VC patient characteristics. Two-tailed p-values less than 0.05 were considered statistically significant. Power and a sample size of the study were calculated on the primary variable stroke volume change. Sample size was calculated to 32 patients in each group with alpha 0.05 and beta 0.15 (Power = 1 - beta = 0.85).

Results

Thirty-four morbidly obese subjects with mean BMI 41.8 ± 4.6 kg/m² participated in the study. A majority were women (23/34). Mean age was 42.8 ± 8.8 years. Preoperative loss of weight during the 3 weeks before surgery was 8.3 ± 1.9 % of total body weight. Duration of significant obesity had been long-lasting (≥ 15 years) in most patients (24/34). Despite common major co-morbidities, preoperative cardiac and pulmonary investigations in the last 10 years before surgery were few, and subject characteristics, co-morbidities, medications, frequencies of cardiac and pulmonary investigations are summarized in Tables 1 and 2.

The mean postoperative hospital length of stay was 1.1 days (range 1-3). Thirty-day mortality rate was zero. One patient was converted to open surgery due to multiple adherences. No postoperative major surgical complications, such as bleeding, anastomotic leaks or re-operations, were observed.

Preoperative *hypovolemia* was found in a majority of MO (24/34, 70.6 %), and was more commonly associated with female gender (p = 0.036), treatment with diuretics (p = 0.031) and no presence of ACE/ARB as anti-hypertensive therapy (p = 0.009). After the volume-challenge, a persistent low level of venous return occurred in 5.9 % (2/34) of the subjects, and 23/34 (67.6 %) of the subjects were euvolemic.

All subjects with preoperative *hypervolemia* (3/34) were male. Preoperative hypervolemia was associated with diabetes mellitus (p = 0.014), use of calcium channel blockers (p = 0.031), and a combined anti-hypertensive therapy (p = 0.003). After volume-challenge hypervolemia was seen in 26.5 % (9/34) of the subjects. Post- VC hypervolemia was seen in MO with diastolic dysfunction (p = 0.013), use of calcium channel blockers (p = 0.048), male gender (p = 0.033), and with pre-VC hypovolemia (p = 0.009) but not with pre-VC euvolemia.

Most of the subjects were volume-responders (29/34, p < 0.001). In non-volume-responders (5/34) medication with calcium channel blockers and systolic LV failure were seen more often (p = 0.006, p = 0.015 respectively) compared to volume-responders. No significant changes in pulse frequency or mean arterial blood pressure were seen following volume-challenge. No association between volume-responsiveness and preoperative state of venous return was found.

Decreased LV or RV systolic function was infrequent; 2/34 and 0/34 respectively. Impaired diastolic properties in LV were more widespread; 64.7 % (22/34) of MO were classified as diastolic dysfunction between grades I to III of IV. After volume-challenge, slightly decreased dynamics of E/A-ratio were seen in association with a Valsalva manoeuvre (p = 0.016). Post-VC E-wave and A-wave velocities were higher compared to baseline (p< 0.001 and p< 0.001 respectively). No significant changes in E/A-ratios were seen after VC. No statistical changes were seen in E' or A'- waves. E/E'-ratios were elevated after VC (p= 0.025), but still remained below 10 (8.7 ± 2). All hemodynamic and echocardiographic data are summarized in Tables 3 and 4.

5

Discussion

The primary aim of our study was to assess the response to a standardized volume-challenge based on IBW-approximation. This VC-regime with 6ml colloids /kg IBW was demonstrated to be a significant intravascular expansion leading to response desirable for preoperative circulatory optimization in the management of RWL-prepared MO, while in a minority of subjects leading to transient "hypervolemia".

Results of our study indicate that characteristics of fluid therapy in MO should be restrictive rather than liberal. In this study population, preoperative hypovolemia and signs of pathological instability in filling pressures were found in most of MO, as shown in an earlier study (8). After the VC, substantial changes in non-dynamic and dynamic echocardiographic indices were observed, and hypovolemia was ceased in most MO.

In addition, despite the relative minute amount of colloid fluids administered, 26.5 % of the study patients were transiently hypervolemic after the VC, likely related to the infusion rate of the VC. Moreover, we found no association between preoperative state of venous return and volume-responsiveness regardless of functional echocardiographic monitoring (25). These findings may be due to decreased compliance of LV in MO, a pathological pressure –volume relationship in LV (21, 22) in combination with increased intra-abdominal pressures (26). In concordance with results published recently (16), our findings indicate that volume therapy is needed in bariatric surgery, but not a liberal volume infusion program.

Pronounced DT and E/A-ratio variation were frequently observed during spontaneous breathing as signs of pathological instability in filling pressures. Reversed E/A-ratios appeared during a Valsalva manoeuvre in all these patients and diastolic function was classified as pseudo-normalized. This filling pattern was called "unstable filling pressures" in this study. Hence, pronounced spontaneous breathing variation of Dt and E/A may function as a powerful predictor of decreased compliance in LV and instability in filling pressures, and should be studied further.

TDI is a useful modality in comprehensive cardiac diagnostics. However, in our experience, monitoring volume-challenge by use of TDI adds no additional information with a critical impact for bed-side decision-making. In our opinion, conventional Doppler indices are better and more robust for this purpose than TDI. Thus, in MO, monitoring ΔSV together with conventional dynamic transmitral indices provides sufficient information about volume-responsiveness, limitations in global stressed volume, and pressure-volume relationship in LV (22, 27). In addition, we confirmed that where there are physical limitations for signal acquisition related to body habitus as in MO, detailed comprehensive assessment of filling pressures can be difficult and time-consuming.

We chose to evaluate volume-responsiveness by measuring TTE-derived ΔSV by LVOT-method in VC because of high reproducibility and feasibility (28). Theoretically passive leg raising manoeuvre (PLR) is an alternative for bringing about a change in venous return (29, 30). However, PLR is not practical in morbidly obese patients due to abdominal obesity and heavy legs, obstructive airway anatomy, cranially positioned diaphragm, and low functional residual capacity/closing volume-ratio (10, 31, 32).

There are several major limitations in the study. The single-centre and not-randomized study design may have had an impact on sampling. In addition, the post-fluid challenge echocardiography was subject to observer bias due to the non-blinded study design. The software limitations of the ultrasound device and the transducer used in this study may have had an effect on the TDI measurements per se and the interpretation of the obtained TDI data.

Moreover, feasibility of transthoracic echocardiography as a method can be reduced by obesity per se. Substantial limitations are likely to occur with extreme BMI-levels and abdominal obesity. Standardization of echocardiographic signal acquisition and analysis was maintained as much as possible through using only an experienced sonographer for data

6

collection. Feasibility, time consumption and acquisition circumstances for TTE in MO were beyond the scope of this article, but were assessed recently in our previous study (8).

It is possible that increased intra-abdominal pressures (IAP) in MO may have affected the results (26, 33), and intra-abdominal pressures were not measured or controlled. Commonly occurring (in severe obesity) increased liver size (liver steatosis) in combination with increased intra-abdominal pressure may have an effect on inferior vena cava size and the venous return of the heart. It is clear that a high intra-abdominal pressure level (>20mmHg) can lead to collapse of the inferior vena cava despite high venous pressure, and this can contribute to limitation of venous return (13).This phenomenon may be accentuated in hypovolemia and hence increase inferior vena cava dynamics and affect the measurements and estimation of right atrial pressure performed with transthoracic echocardiography. On the other hand, one may assume that significant pre-operative weight loss (> 6 - 8% of total body weight; in our study > 8 %) should minimize these effects and even decrease intra-abdominal pressure. In addition, in this study ordinary IVC dynamics were seen in all patients appealing to the reliability of results.

Our study was aiming to investigate loading conditions in direct association with volume-challenge in preoperative setting, and only preoperative data were collected. Thus, possible later effects of volume-challenge were not evaluated in this study protocol. On the other hand, all patients were studied preoperatively without bias caused by anaesthetics. When interpreting the results, it should be taken into account that all patients were rehydrated regardless of pre-VC level of venous return, in order to assess the safety of the VC-regime comprehensively.

Conclusions

The volume-challenge regime with 6 ml colloids/kg ideal body weight was adequate and safe for preoperative management in RWL-prepared MO. There is a potential risk of hypervolemia if liberal preoperative volume regimes are implemented. In volume-challenge, conventional Doppler indices seem to be more informative concerning ventricular compliance compared to TDI, in the morbidly obese.

Acknowledgements

Substantial contributions to the study concept, design, data collection and analysis and statistics were made by the author T.P. T.P., D.K., R.A. and O.W. contributed to analysis and interpretation of data. All authors helped in article preparation. The authors of the study would particularly like to thank and show appreciation to Michael Haney for excellent editing support for this study.

This research was supported by the Norrbotten County Council.

Conflict of interest: There are no conflicts of interest to disclose.

7

Tables 1-4.

Table 1. Patient characteristics, co-morbidities (number of cases or mean value ± SD). Morbidly obese patients (MO), n=34.

Parameter	***MO***
Characteristics	
Age (years)	42.8 ± 8.8
Gender, Female (n)	23/34
Duration of obesity ≥ 15 years (n)	24/34
Waist circumference (cm)	136 ± 14.7
BMI (kg/cm2) at the day of surgery	41.8 ± 4.6
BSA m^2	2.3 ± 0.2
Height (cm)	170.8 ± 8.7
Weight (kg) at the day of surgery	122.5 ± 17.9
Preoperative loss of weight in three weeks (%)	8.3 ± 1.9
Preoperative loss of weight in three weeks (kg)	11.3 ± 3.6
Smoker (n)	12/34
Dyspnoea (in MET<4) (n)	13/34
Co-morbidities	
Hypertension (n)	17/34
Diabetes mellitus (n)	12/34
Bronchial asthma/COPD (n)	14/34
OSAS/OHS (n)	9/34

Abbreviations: BMI, body mass index; BSA, body surface area; Obstructive sleep apnoea syndrome; OHS, Obesity hypoventilation syndrome; COPD, chronic obstructive pulmonary disease; MET, metabolic equivalent of task; SD, standard deviation of mean values. Morbidly obese group (MO), n=34.

8

Table 2. Regular preoperative medication on the day of surgery, cardiac and pulmonary investigations in the last 10 years (%, number of cases). Morbidly obese patients (MO), n=34.

Medication		
Beta-blockers	4/34	(11.8 %)
ACE/ARB	9/34	(26.5 %)
Calcium channel blockers	4/34	(11.8 %)
Diuretics	8/34	(23.5 %)
Combination therapy (consisting ≥ 2 of medications above)	9/34	(26.5 %)
Cardiac and pulmonary diagnostics preoperatively; last 10 years		
Echocardiography/Dobutamine stress echocardiography	3/34	
Spirometry/lung function testing	4/34	
Exercise testing / cardiopulmonary exercise testing	2/34	
Single-photon emission computed tomography (SPECT)	0/34	
PCI	1/34	

Abbreviations: ACE/ARB, angiotensin converting enzyme inhibitors/angiotensin receptor blockers; PCI, percutaneous coronary intervention. Morbidly obese group (MO), n=34.

Table 3. Summary of hemodynamic parameters (% or number of cases or mean value ± SD) before and after volume challenge.

Parameter	*MO pre*	*MO post*	*pT/Chi-2*
MAP (mmHg)	91 ± 14.4	86.4 ± 9.5	NS
Heart rate/min	73.2 ± 13	74.1 ± 12.4	NS
Stroke volume (ml)	66.1 ± 12.2	79.5 ± 14.4	< 0.001
Δ SV (%)	NA	16.6 ± 7	< 0.001*
Volymresponder (%)	NA	85.3 %	< 0.001*
eRAP -3 to 2 or 0 to 5mmHg	24/34	2/34	< 0.001*
eRAP 5-10 mmHg	7/34	23/34	< 0.001*
eRAP > 10 mmHg	3/34	9/34	NS*
Prevalence of hypovolemia	24/34 (70.6 %)	2/34 (5.9 %)	<0.001*
Prevalence of euvolemia	7/34 (20.6%)	23/34 (67.6 %)	<0.001*
Prevalence of hypervolemia	3/34 (8.8 %)	9/34 (26.5 %)	NS*

Abbreviations: Systolic (SAP), mean (MAP) and diastolic (DAP) arterial blood pressure; ΔSV, change of stroke volume; eRAP, estimated right atrial pressure; T, independent sample t-test; *, Chi-Square or Fischer's exact test; NS, not significant; NA, not applicable; SD, standard deviation of mean values; n, number of cases; p, p-value; MO pre, morbidly obese group before volume challenge; MO post, morbidly obese group after volume challenge. Morbidly obese group (MO), n = 34.

10

Table 4. Summary of echocardiography parameters (number of cases or mean value ± SD and range) before and after volume challenge.

Parameter	*MO pre*	*MO post*	*pT*
Non-dynamic indices			
IVCmax (mm)	14.8 ± 2.9	18.8 ± 2.5	<0.001
IVCCI ≥ 50 %	24/34	14/34	0.04*
IVCCI (%)	56.5 ± 14.1	44.7 ± 13.1	<0.001
LAd (mm)	31.4 ± 5.7	35.7 ± 4.9	0.002
LVEDd (mm)	48.8 ± 6.2	50.9 ± 4.9	NS
LVEDA (SAX)	19.5 ± 3.7	22.7 ± 4.0	< 0.001
FS (%)	33.9 ± 5.8	35.9 ± 6.1	NS
EF (%)	58.7 ± 5.1	59.5 ± 7	NS
RVEDd (mm)	34.1 ± 4	36 ± 4.9	NS
TAPSE (mm)	23.5 ± 3.5	26.2 ± 4.4	0.008
Dynamic indices			
Stroke volume (ml)	66.1 ± 12.2	79.5 ± 14.4	< 0.001
VTI LVOT (cm)	17 ± 2	20.6 ± 2.7	< 0.001
E/A	1.4 ± 0.34	1.4 ± 0.54	NS
E (m/s)	0.84 ± 0.14	1.0 ± 0.12	< 0.001
A (m/s)	0.62 ± 0.14	0.75 ± 0.16	< 0.001
DT (ms)	178 ± 35.4	177 ± 36	NS
E’ septum (cm/s)	11.3 ± 2.6	12.0 ± 2.6	NS
A’ septum (cm/s)	12.2 ± 5.7	10.7 ± 2.2	NS
E/E’	7.6 ± 2	8.7 ± 2	0.025

Abbreviations:; IVC, inferior vena cava; Δ IVC ≥ 50%, respiratory variation of inferior vena cava 50 %; LAd, left atrium anterior-posterior diameter in end-systole; LVEDd, left ventricle (LV) end-diastolic diameter; FS, fractional shortening of LV; EF, ejection fraction of LV; RVEDd, right ventricle end-diastolic diameter; TAPSE, tricuspid annular plane systolic excursion; LVEDA (SAX), left ventricle end-diastolic area in short axis projection; E/A, ratio of E wave of the mitral inflow by A wave of the mitral inflow; E, E wave of the mitral inflow; A, A wave of the mitral inflow; DT, deceleration time of E wave; NS, not significant; SD, standard deviation of mean values; T, independent sample t-test; *, Fisher’s exact test; p, a p-value; MO pre, morbidly obese group before volume challenge; MO post, morbidly obese group after volume challenge. Morbidly obese group (MO), n = 34.

11

References:

1. WHO, Obesity and overweight [database on the Internet]2010.
2. SOReg - Scandinavian Obesity Surgery Register. [database on the Internet].
3. The expert group rapport of the national guidelines for bariatric surgery (NIOK), Sweden2009.
4. Deitel M. Overweight and obesity worldwide now estimated to involve 1.7 billion people. Obes Surg2003 Jun;13(3):329-30.
5. Benotti PN, Still CD, Wood GC, Akmal Y, King H, El Arousy H, et al. Preoperative weight loss before bariatric surgery. Arch Surg2009 Dec;144(12):1150-5.
6. Liu R, Sabnis A, Forsyth C, Chand B. The Effects of Acute Preoperative Weight Loss on Laparoscopic Roux-en-Y Gastric Bypass. Obesity Surgery2005;15(10):1396-402.
7. Fris R. Preoperative Low Energy Diet Diminishes Liver Size. Obesity Surgery2004;14(9):1165-70.
8. Poso T, Kesek D, Aroch R, Winso O. Rapid Weight Loss Is Associated with Preoperative Hypovolemia in Morbidly Obese Patients. Obes Surg2012 Oct 21.
9. Alpert MA, Chan EJ. Left ventricular morphology and diastolic function in severe obesity: current views. Rev Esp Cardiol2012 Jan;65(1):1-3.
10. Adams JP, Murphy PG. Obesity in anaesthesia and intensive care. Br J Anaesth2000 Jul;85(1):91-108.
11. Tavares ID, Sousa AC, Menezes Filho RS, Oliveira MH, Barreto-Filho JA, Brito AF, et al. Left ventricular diastolic function in morbidly obese patients in the preoperative for bariatric surgery. Arq Bras Cardiol2012 Mar 27.
12. Poirier P, Alpert MA, Fleisher LA, Thompson PD, Sugerman HJ, Burke LE, et al. Cardiovascular evaluation and management of severely obese patients undergoing surgery: a science advisory from the American Heart Association. Circulation2009 Jul 7;120(1):86-95.
13. Nguyen NT, Wolfe BM. The physiologic effects of pneumoperitoneum in the morbidly obese. Ann Surg2005 Feb;241(2):219-26.
14. Popescu WM, Schwartz JJ. Perioperative Considerations for the Morbidly Obese Patient. Advances in Anesthesia2007;25:59-77.
15. Ogunnaike BO, Jones SB, Jones DB, Provost D, Whitten CW. Anesthetic considerations for bariatric surgery. Anesth Analg2002 Dec;95(6):1793-805.
16. Jain AK, Dutta A. Stroke volume variation as a guide to fluid administration in morbidly obese patients undergoing laparoscopic bariatric surgery. Obesity Surgery2010;20(6):709-15.
17. O'Neill T, Allam J. Anaesthetic considerations and management of the obese patient presenting for bariatric surgery. Current Anaesthesia & Critical Care;21(1):16-23.
18. Katkhouda N, Mason RJ, Wu B, Takla FS, Keenan RM, Zehetner J. Evaluation and treatment of patients with cardiac disease undergoing bariatric surgery. Surg Obes Relat Dis Sep-Oct;8(5):634-40.
19. Canty DJ, Royse CF, Kilpatrick D, Bowman L, Royse AG. The impact of focused transthoracic echocardiography in the pre-operative clinic. Anaesthesia;67(6):618-25.
20. Brennan JM, Blair JE, Goonewardena S, Ronan A, Shah D, Vasaiwala S, et al. Reappraisal of the use of inferior vena cava for estimating right atrial pressure. J Am Soc Echocardiogr2007 Jul;20(7):857-61.
21. Nagueh SF, Appleton CP, Gillebert TC, Marino PN, Oh JK, Smiseth OA, et al. Recommendations for the evaluation of left ventricular diastolic function by echocardiography. J Am Soc Echocardiogr2009 Feb;22(2):107-33.

22. Backer DD, Cholley BP, Slama M, Vieillard-Baron A, Vignon P, editors. Hemodynamic Monitoring Using Echocardiography in the Critically Ill: Springer-Verlag Berlin Heidelberg; 2011.
23. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, et al. Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology. Journal of the American Society of Echocardiography2005;18(12):1440-63.
24. Berger M, Haimowitz A, Van Tosh A, Berdoff RL, Goldberg E. Quantitative assessment of pulmonary hypertension in patients with tricuspid regurgitation using continuous wave Doppler ultrasound. J Am Coll Cardiol1985 Aug;6(2):359-65.
25. Pinsky MR, Teboul JL. Assessment of indices of preload and volume responsiveness. Curr Opin Crit Care2005 Jun;11(3):235-9.
26. Vivier E, Metton O, Piriou V, Lhuillier F, Cottet-Emard JM, Branche P, et al. Effects of increased intra-abdominal pressure on central circulation. Br J Anaesth2006 Jun;96(6):701-7.
27. Iijima T. Complexity of blood volume control system and its implications in perioperative fluid management. J Anesth2009;23(4):534-42.
28. Beaulieu Y, Marik PE. Bedside ultrasonography in the ICU: part 1. Chest2005 Aug;128(2):881-95.
29. Monnet X, Teboul JL. Passive leg raising. Intensive Care Med2008 Apr;34(4):659-63.
30. Jabot J, Teboul JL, Richard C, Monnet X. Passive leg raising for predicting fluid responsiveness: importance of the postural change. Intensive Care Med2009 Jan;35(1):85-90.
31. Biring MS, Lewis MI, Liu JT, Mohsenifar Z. Pulmonary physiologic changes of morbid obesity. Am J Med Sci1999 Nov;318(5):293-7.
32. Brodsky JB. Positioning the morbidly obese patient for anesthesia. Obes Surg2002 Dec;12(6):751-8.
33. Lambert DM, Marceau S, Forse RA. Intra-abdominal pressure in the morbidly obese. Obes Surg2005 Oct;15(9):1225-32.

13