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ORIGINAL CONTRIBUTIONS

The Effects of Perioperative Factors on Early Postoperative Morbidity in Bariatric Surgery

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Abstract

Purpose This study aims to examine the predictive role of obesity-type-related indexes and perioperative intraabdominal pressure measurements for early postoperative complications following bariatric surgery.

Materials and Methods Sixty-seven female patients with obesity who underwent bariatric surgery (laparoscopic sleeve gastrectomy or gastric bypass) were included in this study. Obesity-related indexes (BMI, waist/hip ratio, and waist/height ratio) were calculated using patient data. Intraoperative hemodynamic measurements and intraabdominal pressure measurements were done at the beginning and at the end of the operation. Intraabdominal pressure measurements were done using both bladder port and trocar port. Patients were followed for early postoperative complications.

Results Among 67 patients included, 22 developed early postoperative complications (32.8%), mostly pulmonary (20.9%). Trans-trocar IAP measured at the beginning of the operation emerged as the single independent predictor of postoperative complications (OR, 40.3; $p=0.002$). Based on ROC analysis, AUC for predicting complications was 0.955 ($p<0.01$). Optimal cutoff point (≥ 14.5 mmHg) was associated with 100% sensitivity and 82% specificity. In addition, there were weak but significant positive correlations between trans-trocar IAP-beginning and BMI ($r=0.443$, $p<0.001$), waist/hip ratio ($r=0.434$, $p<0.001$), and waist/height ratio ($r=0.539$, $p<0.001$).

Conclusion Findings of this study suggest that a high baseline intraabdominal pressure predicts a higher risk for early postoperative complications following bariatric surgery. This information would help improve patient care. Further large studies are warranted.

Keywords Bariatric surgery · Gastric bypass · Sleeve gastrectomy · Postoperative complication · Intraabdominal pressure · Central obesity

Key Points
Obesity is associated with increased intraabdominal pressure.
Bariatric surgery may occasionally be associated with obesity-related complications.
Intraabdominal pressure predicts early postoperative complications.
This may aid in early identification of patients at risk and improve patient care.

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Introduction

Obesity is a worldwide epidemic affecting both adult and pediatric population [1]. In the USA, more than one-third of adult males and females are estimated to be suffering from obesity, as defined by a body mass index ≥ 30 [2]. Such an excess weight is not only associated with impaired quality of life and psychosocial problems, but considerably morbidity and mortality in the long term. Cardiovascular and cerebrovascular diseases, diabetes, cancers, sleeping disorders, hepatobiliary diseases, gout, and osteoarthritis are among the conditions associated with obesity [1]. The main goal of the obesity management is weight loss, which has been shown to reduce these long-term conditions in a dose-related manner [1].

Although weight loss can be attained through non-surgical management strategies including exercise, diet, medications, behavioral therapy, and subsequent lifestyle modifications, bariatric surgery is the most effective treatment modality in patients with morbid obesity [1, 3]. Due to recent advances in surgical techniques, bariatric surgery is relatively a safe procedure; however, early postoperative complications are not rare [4]. Identifying predictors of early complications would improve patient care and surgical outcomes.

Increases in BMI and morbid obesity have shown to be associated with chronic intraabdominal pressure [5]. Increased intraabdominal pressure and abdominal compartment syndrome may have deleterious effects on organ systems. Increased intraabdominal pressure is associated with an increase in obesity-related comorbidities [6]. Such increase in intraabdominal pressure and resulting increased morbidity risk have also been speculated to be a function of central obesity [7]. The relations between indexes for obesity type, intraabdominal pressure, and co-morbidities have yet to be revealed. Bariatric surgery itself causes increases in intraabdominal pressure compared to preoperative values [8]. Thus, the effects of these parameters on early postoperative complications following bariatric surgery need to be examined.

This study aims to examine the potential predictors of early postoperative complications after bariatric surgery including obesity indexes and perioperative intraabdominal pressure.

Methods

Patients

Sixty-seven female patients with obesity who underwent bariatric surgery (laparoscopic sleeve gastrectomy or gastric bypass) were included in this study. The following were the inclusion criteria: American Society of Anesthesiologists (ASA) II-III physical status, body mass index (BMI) > 35 kg/m^2, and age between 18 and 65 years. Smokers, patients who underwent revision bariatric surgery, or major abdominal surgery were excluded. Obesity-related indexes (BMI, waist/hip ratio, and waist/height ratio) were calculated using patient data. The study protocol was approved by local ethics committee (Ethics Committee for Clinical Studies, Marmara University, Medical Faculty; date, January 3, 2020; no, 09.2020.133). All patients provided informed consent prior to study entry and the study was conducted in accordance with the Declaration of Helsinki. The study was registered to ClinicalTrials.gov with identifier NCT 04,929,639.

Anesthesia Management

Patients were monitored with ECG, pulse oximeter, non-invasive blood pressure, and bispectral index (BIS) measurements. Adjusted weights were used in dose calculations as suggested by the Society of Bariatric Anesthesia Association. Propofol 2 mg/kg, remifentanil 1 μg/kg, and rocuronium 0.6 mg/kg were administered for anesthesia induction. Total intravenous anesthesia with propofol and remifentanil was used for maintenance, and the initial doses were as follows: propofol 6–10 mg/kg/h and remifentanil 0.5 μg/kg/h. Propofol and remifentanil doses were adjusted to keep BIS between 40 and 45.

Perioperative Measurements

Blood urinary nitrogen (BUN), creatinine, and lactate concentrations were measured 24–48 h before and 12 h after surgery. Intraoperative intraabdominal pressure and hemodynamic measurements were done at two time points: at the beginning and at the end of the operation. Immediately after intubation, when the patient is lying in supine position, intraabdominal pressure measurement was made from the bladder probe (trans vesicular IAP-beginning). Then, after the surgical field antisepsis, when the trocar was placed by the surgeon, another measurement was made from the trocar port (trans-trocar IAP-beginning). Baseline trans-trocar measurements were done before insufflation. Another trans-trocar IAP measurement was done just after CO2 evacuation and before trocar removal (trans-trocar IAP-end). Trans-trocar measurements were done after checking the trocar and assuring that it is free of any obstruction. To rule out any obstruction or blockade by organs, thus, to prevent incorrect measurements, certain measures were taken during trans-trocar pressure measurements (Supplementary video). Firstly, the patients were under deep muscular relaxation, which would prevent pressure increases due to increased abdominal muscle tonus. Just prior to the placement of the trocar, the surgeon examined the entrance digitally to make sure that there was no obstruction. Then, after placement of the trocar and before pressure measurements, absence of any obstruction was confirmed by video images.

Just before extubation, another trans-vesicular IAP measurement was done (trans-vesicular IAP-end). In addition, mean blood pressure and heart rate measurements were recorded at the beginning and end of the operation.

Follow-Up

Patients were followed during early postoperative period (for 30 days) and complications were recorded. In addition, complications were classified using Clavidien-Dindo classification system [9].

Statistical Analysis

SPSS (Statistical Package for Social Sciences) version 21 software was used for data analysis. Hypothesis tests and graphical methods were used to test the distribution of continuous variables. Student *t* test for independent samples or Mann–Whitney *U* test was used to test between-group differences. Receiver operating characteristics (ROC) curves were drawn for parameters associated with development of postoperative complications and areas under curve (AUC) were calculated. Multivariate analysis using logistic regression was done to identify significant independent predictors of postoperative complications. For parameters with potential predictive value, optimal cut-off values were estimated along with their sensitivity and specificities for predicting subsequent postoperative complications. Correlations between continuous variables were tested using Pearson's correlation analysis or Spearman's test, where appropriate. Two-sided p values < 0.05 were considered indication of statistical significance.

Results

Among 67 patients, 22 developed early postoperative complications (32.8%). Pulmonary complications were the most common (atelectasis 14.9%, hypoxia 6.0%), followed by infection (6.0%), bleeding (3.0%), hernia (1.5%), and anastomosis leakage (1.5%). No complication related to trans-vesicular or trans-trocar pressure measurements was seen.

Table 1 Univariate analysis of the possible effects of factors on the development of postoperative complications

Factor	No complication (n = 45)	Any complication (n = 22)	p*	AUC
Demographics				
Age, y	38.9 ± 10.0	44.3 ± 8.9	0.036	0.644
Obesity parameters				
BMI, kg/m2	45.2 ± 5.1	49.5 ± 7.2	0.035	0.659
Waist/hip ratio	0.91 ± 0.08	0.97 ± 0.08	0.005	0.710
Waist/height ratio	0.77 ± 0.09	0.84 ± 0.08	0.002	0.727
Renal parameters				
Preoperative BUN	12.0 ± 3.1	12.7 ± 3.4	0.343	0.571
Postoperative BUN	10.2 ± 3.0	12.1 ± 5.8	0.186	0.599
BUN change	-1.8 ± 2.6	-0.6 ± 3.2	0.199	0.596
Preoperative creatinine	0.62 ± 0.13	0.67 ± 0.14	0.253	0.586
Postoperative creatinine	0.61 ± 0.14	0.71 ± 0.17	0.027	0.667
Creatinine change	-0.01 ± 0.10	0.04 ± 0.14	0.232	0.588
Preoperative lactate	1.2 ± 0.5	1.3 ± 0.7	0.941	0.494
Postoperative lactate	1.4 ± 0.7	1.7 ± 1.1	0.474	0.554
Lactate change	0.2 ± 0.5	0.3 ± 0.7	0.490	0.548
Cardiac parameters				
MAP-int	86.5 ± 9.2	94.8 ± 8.3	0.001	0.761
MAP-ext	89.8 ± 8.4	96.1 ± 6.6	0.003	0.724
HR-int	82.4 ± 11.1	89.8 ± 8.7	0.006	0.708
HR-ext	86.8 ± 9.0	90.9 ± 9.0	0.084	0.634
Intraabdominal pressure parameters				
Trans vesicular IAP – int	12.0 ± 1.3	13.7 ± 0.9	< 0.001	0.862
Trans vesicular IAP – ext	12.3 ± 1.3	14.5 ± 0.7	< 0.001	0.925
Trans-trocar IAP – int	13.8 ± 0.9	15.8 ± 0.7	< 0.001	0.955
Trans-trocar IAP – ext	14.2 ± 1.0	16.2 ± 1.3	< 0.001	0.879

Data presented in mean ± standard deviation. *p value for the difference between the two groups; † *p* value for receiver operating characteristic (ROC) analysis; BMI, body mass index; BUN, blood urinary nitrogen; MAP, mean arterial pressure; HR, heart rate; IAP, intraabdominal pressure; AUC, area under curve; int., at the time of intubation; ext. at the time of extubation

Table 2 Detailed summary of complications based on Clavien-Dindo classification system

Clavien-Dindo class	n (%)	Type*
No complication	45 (67.2%)	-
I	1 (1.5%)	hematuria (1)
II	12 (17.9%)	atelectasis (10) †, wound infection (2)
IIIB	3 (4.5%)	bleeding (1), subcutaneous abscess (1), incarcerated hernia (1)
IVA	5 (7.5%)	hypoxia (3), anastomosis leak (1), abscess at trocar site
IVB	1 (1.5%)	hypoxia (1)

*Numbers in parentheses indicate number of patients. † All these patients were symptomatic patients with dyspnea and decreased oxygen saturation. In addition to respiratory physiotherapy, all received inhaled bronchodilators, and some received antibiotics when necessary

Analysis of Predictors for Complications

Table 1 compares the patients who developed early postoperative complications with the patients who did not. Detailed summary of complications based on Clavien-Dindo classification system is given in Table 2. In addition, AUC of ROC curves of the same factors for predicting complications are also given. In univariate analysis, complications were associated with higher age, higher obesity indexes, higher postoperative creatinine, higher heart rate and mean arterial pressure as well as higher intraabdominal pressure. All AUC values for ROC curves of intraabdominal pressure measurements were above 0.850, indicating very high predictive value. Multivariate analysis of intraoperative cardiac and intraabdominal pressure parameters identified only trans-trocar IAP measured at the beginning of the operation as the only significant intraoperative predictor of postoperative complications (OR, 47.1; 95% CI, 2.2–1018.9; $p = 0.014$). When trans-trocar IAP-beginning was included in the final multivariate analysis along with age, BMI, waist/hip ratio, waist/height ratio, and postoperative creatinine, again trans-trocar IAP-beginning emerged as the single independent predictor of postoperative complications (OR, 40.3; 95% CI, 4.0–404.0; $p = 0.002$).

When intraabdominal pressures of patients with and without each complication type were compared, patients with pulmonary ($p < 0.001$) and infectious problems ($p = 0.029$) had significantly higher baseline trans-trocar IAP when compared to the patients without such complications. However, baseline trans-trocar IAP was similar across patients with and without hernia (0.687), anastomosis leak ($p = 0.299$), or bleeding (0.246).

Figure 1 shows the ROC curve of trans-trocar IAP-beginning for the development of postoperative complications (AUC, 0.955; 95% CI, 0.906–1.000; $p < 0.001$). An optimal cutoff point (≥ 14.5 mmHg) was associated with 100% sensitivity and 82% specificity.

Correlations

There were weak but significant positive correlations between trans-trocar IAP-beginning and BMI ($r = 0.443$, $p < 0.001$), waist/hip ratio ($r = 0.434$, $p < 0.001$), and waist/height ratio ($r = 0.539$, $p < 0.001$).

Discussion

Findings of this study emphasize the importance of baseline intraabdominal pressure levels in predicting early postoperative complications in patients with morbid obesity who represent a group of patients that normally have higher intraabdominal pressure levels compared to patients without obesity. To the best of our knowledge, this is the first study examining the roles of an array of factors including intraabdominal pressure and obesity indexes in predicting early postoperative complications following bariatric surgery.

Morbid obesity is known to cause chronic increase in intraabdominal pressure. A previous study has estimated that every 1 kg/m^2 BMI increase was associated with 0.07 mmHg increase in intraabdominal pressure as measured using Veress needle. Since many organ systems including respiratory, renal, cardiovascular, and central nervous system may be affected by increased intraabdominal pressure [5, 10], chronic effects on these organs may contribute to the development of comorbidities. Several studies so far have examined the relation between increased intraabdominal pressure and comorbidities among patients with obesity and increased intraabdominal pressure was found to be associated with an increase in comorbidities [6, 7, 11], although contradictory findings also exist [12]. In the study by Lambert et al., number of comorbidities correlated with intraabdominal pressure and patients with ≥ 5 comorbidities had significantly higher intraabdominal pressure when compared to the patients with < 5 comorbidities [7]. However, in multivariate analysis, only age emerged as a significant predictor. Similarly, Varela et al. found a positive correlation between intraabdominal pressure and number of comorbidities [6]; however, Wilson et al. did not find such an association [12].

Intraabdominal pressure seems to further increase after bariatric surgery [8], which may make the bariatric surgery itself a risk factor for the organ effects of increased

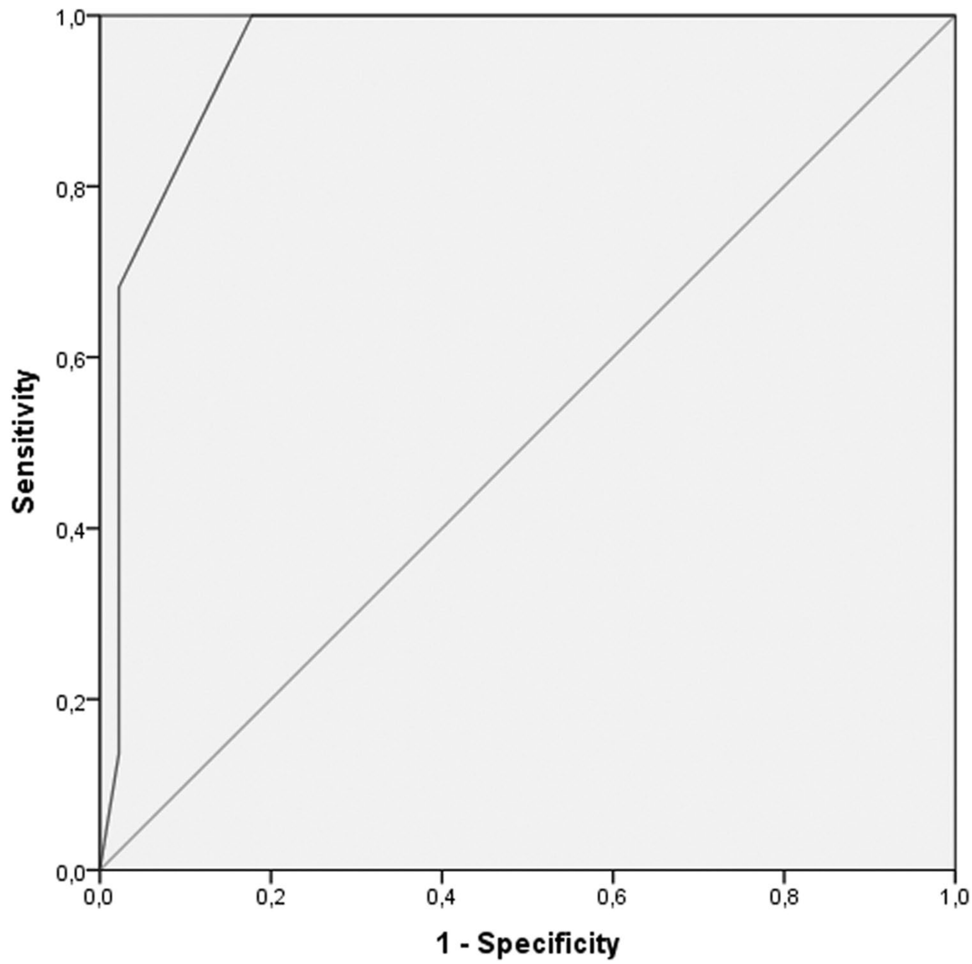

Fig. 1 ROC curve of trans-trocar IAP at the beginning of the operation for the development of postoperative complications

abdominal pressure. In a study examining intraabdominal pressure changes during laparoscopic and open gastric bypass operation, a significant increase was evident compared to baseline for both techniques [8]. However, the increase was lower in the former technique and returned to baseline earlier (2 days versus 3 days). However, possible effects of increased intraabdominal pressure on immediate complications following bariatric surgery have not been examined so far. In this study, a strong relation was found between increased intraabdominal pressure and early postoperative complications. Most complications were pulmonary in nature. Besides its effects on other organ systems [13–17], intraabdominal hypertension or abdominal compartment syndrome seem to exert profound effects on pulmonary function [17]. Elevated intraabdominal pressure may cause compression on the lungs due to the elevation of diaphragm and adversely affect pulmonary function. This may explain the high incidence of postoperative hypoxia and atelectasis as well as the association between intraabdominal hypertension and postoperative complications observed in the present study.

A recent study defined benchmarks for optimal surgical outcomes after bariatric surgery (Roux-en-Y gastric bypass and sleeve gastrectomy) [18]. That study was conducted on patients with well-defined low risk, i.e., absence of previous abdominal surgery, additional procedures, and certain comorbidities, as well as patients with BMI ≤ 50 kg/m^2, or age ≤ 65 years. In that study, within 30 postoperative days, benchmark value for any complication was 9.0% and 11.0% for Roux-en-Y gastric bypass and sleeve gastrectomy, respectively, which are well below the 30-day figure found in the present study (32.8%). In addition, the benchmark value for grade ≥ IIIa Clavien-Dindo complication rate was 5.0%, which is still far below the figure found in the present study (13.5%). These differences may be explained by the higher risk profile in the present study which included patients with a BMI > 50 (19.4%) and patients with comorbidities.

A 2013 study from Ukraine, a total of 53 patients with morbid obesity who underwent laparotomic bariatric surgery were included [19]. That study compared groups based on BMI in terms of comorbidities and postoperative outcomes including pressure changes, rather than examining the direct effect of intraabdominal pressure on postoperative morbidities. Nevertheless, results give an idea about potential consequences of preoperative high intraabdominal pressure values. Indirect trans-vesical pressure measurements were done. At baseline, intraabdominal pressure exceeded 12 mmHg in all patients. Patients with a BMI ≥ 50 kg/m^2 had significantly higher intraabdominal pressure at baseline (15.7 vs. 13.1 mmHg, $p = 0.017$), and a significant correlation was found between BMI and intraabdominal pressure. In addition, comorbidities were more common in the higher BMI group. Early after surgery (first day), significantly higher increase was observed in patients with higher BMI (19.7 mmHg vs. 17.4 mmHg, $p = 0.0053$), which returned to normal levels in the subsequent 2 to 3 days. However, abdominal compartment syndrome, which may have fatal consequences and defined as an increase in intraabdominal pressure over 20 mmHg was seen in 9% and 29% of the lower BMI and higher BMI groups, respectively, and the difference did not reach statistical significance possibly due to small sample size. None of the patients developed organ failure or wound dehiscence. The authors concluded that patients with morbid obesity show a high level of adaptation to acute increase in intraabdominal pressure after bariatric interventions.

Although not investigated in the setting of bariatric surgery, the effect of increased intraabdominal pressure on postoperative complications has been examined for abdominoplasty. In that small study with 17 patients who underwent abdominoplasty for esthetic reasons, three patients had respiratory distress and three had wound dehiscence [20]. These patients had high intraabdominal pressure after the operation. Authors concluded that patients with a high trans-vesical intraabdominal pressure were at risk for respiratory distress during early postoperative period, which is in line with our findings.

A study examining the relations between intraabdominal pressure and comorbidities in patients with morbid obesity found higher trans-vesicular intraabdominal pressure in patients with pressure-related comorbidities; however, the authors concluded that intraabdominal pressure was a function of central obesity and that the elevated intraabdominal pressure was due to the direct mass effect of visceral obesity rather than being abdominal compartment syndrome [7]. In the present study, almost all patients had central obesity based on waist/height and waist/hip ratios; therefore, type of obesity could not be examined as a potential predictive factor for complications. However, these indexes did not emerge as significant independent predictor, although higher ratios were obtained in patients with complication on univariate analysis. Only weak correlations were found between intraabdominal pressure and obesity indexes (BMI, weight/height, weight/hip ratio). This may be due to low sample size; nevertheless, we suggest that increased intraabdominal pressure itself may have unfavorable effects on organ systems resulting in early postoperative complications and would like to emphasize the importance of intraoperative pressure measurements in predicting early postoperative complications.

The findings of this study have several implications in clinical setting. Baseline intraabdominal pressure in patients undergoing laparoscopic bariatric surgery seems to have an impact on early postoperative course. Therefore, a simple intraabdominal pressure measurement at the beginning of the operation may help identify patients with relatively high risk for early postoperative complications, particularly respiratory and infectious problems. It would be wise to closely follow patients with high intraabdominal pressure so that early intervention is possible. In such patients, routine use of pulse oximetry in the wards, close monitoring of venous blood gases and hematocrit, and alertness for other signs and symptoms of respiratory impairment, hernia, leakage, or bleeding would improve early postoperative outcomes. For this patient group, no specific or recommended preoperative pulmonary preparation algorithms were routinely used, except for occasional patients apparently needing it. Given the high rate of atelectasis, preoperative physiotherapy can be recommended to all bariatric patients, since identification of high intraabdominal pressure is not feasible preoperatively.

This study has several limitations. First, relatively small sample size might have resulted in insufficient power, particularly for the analyses of individual complication types. Large multi-centric or national cohorts would provide more insight into predictors of postoperative morbidity in general, the role of intraabdominal pressure in particular. Another potential limitation is the lack of a group consisting of patients without obesity, which would allow comparison and provide more relevant clinical information specific for patients with obesity. In addition, mid-term and long-term follow-up would clarify whether these effects are transient. Therefore, our findings should be interpreted within the context of such limitations. Nevertheless, these findings represent preliminary findings underscoring the unfavorable effects of increased intraoperative pressure on early postoperative course in bariatric surgery, possible paving the way to more robust studies in the future with higher methodological quality.

Conclusion

Findings of this study suggest that a high baseline intraabdominal pressure measured directly from the trocar predicts a higher risk for early postoperative complications, particularly pulmonary problems. This information would help improve patient care following bariatric surgery. Studies with larger sample size and different obesity types would shed more light on the issue.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11695-022-05931-2.

Declarations

Ethics Approval All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflict of Interest The authors declare no competing interests.

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