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ORIGINAL SCIENTIFIC REPORT

Periadrenal Volume is a Better Predictor of Prolonged Operative Time in Laparoscopic Retroperitoneal Adrenalectomy than BMI

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Abstract

Background Retroperitoneal laparoscopic adrenalectomy is gaining traction as a minimally invasive technique. One of the purported relative contraindications is BMI given the smaller working space. We hypothesize that other anthropometric measurements may be better predictors of operative time.

Methods An IRB-approved, single-institution, retrospective study of 83 patients who underwent laparoscopic retroperitoneal adrenalectomy evaluated the association of anthropometric measurements taken from cross-sectional imaging and the primary outcome of operative time. Descriptive statistics were performed with Wilcoxon rank-sum test for continuous variables (median; IQR) and Chi-square (n; %) for categorical variables. A linear random effects model was used to model operative time.

Results The majority of the patients were white (40; 48.2%) women (46; 55.4%) with a median age of 54 with interquartile range (IQR) of 43–63 and a median BMI of 27.8 (IQR 21.2–38.6). On univariable analysis, factors that led to longer operative time included right-sided operation ($p = 0.04$), male gender ($p < 0.01$), clinical diagnosis ($p < 0.01$), waist area ($p < 0.01$), waist/hip ratio ($p < 0.01$), periadrenal volume ($p < 0.01$), posterior adiposity index (PAI) ($p < 0.01$) and BMI ($p < 0.01$). Only side, order of operation, and periadrenal fat volume ($p < 0.01$, $p = 0.02$ and $p < 0.01$, respectively) remained independent predictors of increased operative time on multivariable analysis.

Conclusion This study demonstrates that anthropometric measurements, specifically periadrenal fat volume, and side of operation, are better predictors for increased operative time in laparoscopic retroperitoneal adrenalectomies than BMI. This information can help facilitate appropriate patient selection for this operative approach.

Introduction

As compared with traditional open adrenalectomy, laparoscopic adrenalectomy has improved clinical outcomes such as 30-day morbidity, decreased patient stay, less intraoperative blood loss, better pain control and earlier patient mobility [1–3]. Although the more traditional approach has been transabdominal, a retroperitoneoscopic approach has become a popular alternative in recent years. The benefits of the retroperitoneoscopic approach include a more direct approach to the adrenal gland, avoidance of potential adhesions from previous abdominal operations

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and avoidance of repositioning for patients undergoing bilateral adrenalectomy [4–6]. There is also some evidence that suggests the retroperitoneal approach seems to result in shorter times to oral intake and ambulation as well as shorter lengths of stay [7–9]. However, this operation can often be technically difficult in certain patients. The retroperitoneal approach has challenges of being less commonly performed, leading to less awareness and mentorship, and smaller working space, leading to a heightened importance in placement of port sites to avoid instrument collision. An unfamiliar operative view, compared to the more familiar transabdominal approach, also lends to the difficulty of this operation. Prior studies have evaluated the learning curve for the laparoscopic retroperitoneal approach, finding 24–42 cases required to complete the learning curve for the retroperitoneal approach, versus 20–40 for the traditional laparoscopic anterior approach [10]. This is on par with another study that ran a multifactorial logistic regression analysis for laparoscopic adrenalectomy based on various patient and operative factors and found that operative time and complication rate flattened their curves for right adrenalectomy at 30 cases and left at 40 cases [11].

Due to the technically challenging aspects of the retroperitoneal approach, several studies postulated that patient body mass index (BMI) would contribute to the challenge of the retroperitoneoscopic approach [12, 13]; however, BMI itself has not seemed to affect operative times or outcomes [14–16]. This is likely because BMI itself does not necessarily predict larger anthropometric measurements that can affect the difficulty of the retroperitoneal approach, such as the periadrenal or perinephric fat volume. Instead, different studies have calculated various anthropometric measurements to help predict patients better suited for retroperitoneoscopic approach. In 2012, Agcaoglu et al. [17] found that an increase in the perinephric fat and the distance between the adrenal tumor and the upper pole of the kidney increased operative time for the retroperitoneal approach. Lindemann et al. calculated a 'posterior adiposity index' to help select appropriate patients for retroperitoneoscopic approach. This index focused on the skin to Gerota's fascia distance, as well as the perinephric fat distance, as predictors for longer operative time with the retroperitoneal approach [18].

To date, there has been no consensus on which anthropometric measurements best correlate with operative difficulty, and there has not been a study that has evaluated these anthropometric factors while taking into account the surgeon's experience and number of operations performed. Therefore, the objective of this study is to evaluate which anthropometric measurements best predict a longer operative time while accounting for surgeon experience.

Materials and methods

Data source

This is a retrospective cohort study of all patients undergoing retroperitoneoscopic adrenalectomies by two surgeons at a single, tertiary care center (IRB Protocol: AAAD4780). All patients $\geq$12 years of age, with preoperative cross-sectional imaging who underwent complete adrenalectomy from 2007 to 2018, were included in the analysis.

Predictor variables

Demographic, preoperative and intraoperative data was collected, including age, gender, race, ethnicity, height, weight, BMI, clinical diagnosis, date of surgery, side, surgeon, surgeon's order of operation, tumor size and tumor pathology. Operative time was calculated from incision time and surgery end time, as recorded by the circulating nurse on the operating room record.

Methodology for anthropometric measurements

Anthropometric measurements were obtained from preoperatively performed cross-sectional imaging. Figure 1 includes images that depict how these measurements were performed. The measurement 'Anterior–posterior of the waist' was measured on axial slice as the shortest distance through midline from anterior to posterior (A). 'Diameter of waist' was measured as the shortest transverse distance on axial plane (B). 'Diameter of the hips' (C) and 'anterior–posterior of hips' (D) were measured as the largest distance through the femoral head in the axial plane. 'Adrenal space width (E), height (F), anterior–posterior (G), superolateral to inferomedial distance (H) and superomedial to inferolateral distance (I)' are also demonstrated in Fig. 1. 'Subcutaneous fat tissue distance' was the distance from the posterior back musculature to the skin 1 cm below the 12th rib posteriorly (J). The 'perirenal distances' were anteriorly (K) and posteriorly (L) of Gerota's fascia to the most immediate structure at the level of the renal vein. 'Iliac to rib distance' was the shortest distance from the rib to the iliac bone measured on coronal slice (M).

Operative approach

Our practice preference has been the posterior approach; however, this is not used in patients with suspected malignancy, tumors over 6 cm, need to explore the rest of the abdomen, or patients with BMI greater than 40 where it is feared the posterior approach would not be feasible. We

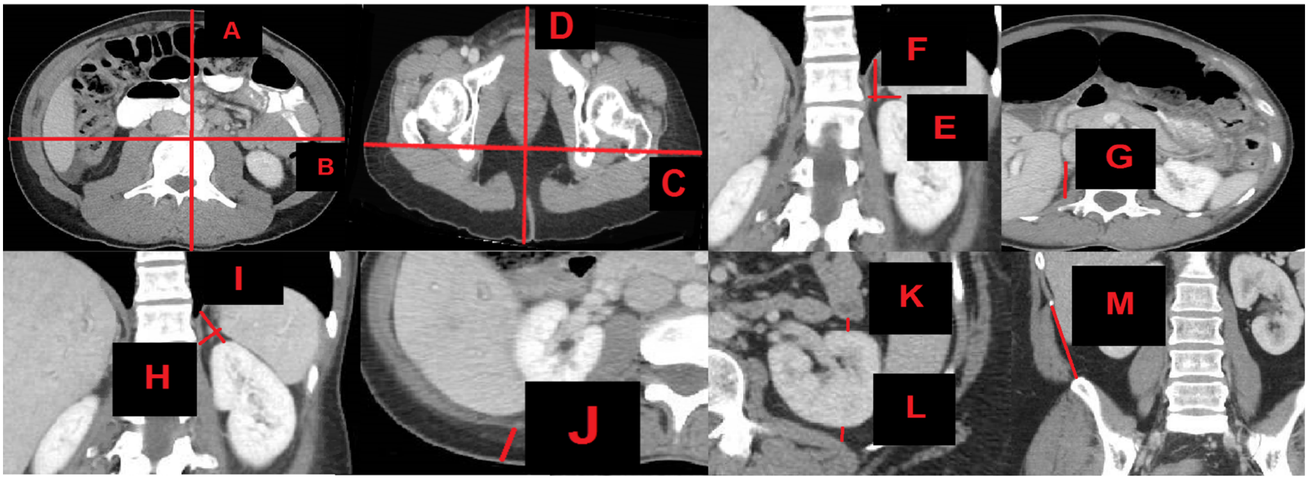

Fig. 1 Anthropometric measurements

do not use ultrasound as an aid as we have found that the ultrasonic waves using a 5–12 mHz probe do not appear be sufficient to clearly distinguish the border of the ribs (especially in patients with thicker subcutaneous tissue), much less any anatomical structures deeper than the rib cage. For our retroperitoneoscopic approach, we use the three trocar technique as described by Dr. Walz in his paper ‘Posterior retroperitoneoscopic adrenalectomy—results of 560 procedures in 520 patients’ [19].

Outcome variables

The primary outcome analyzed was length of operation in minutes. Secondary outcomes were overall complication rate including conversion to open, blood loss requiring a transfusion, renal dysfunction, cardiopulmonary event, incisional hernia or death.

Statistical analysis

Descriptive statistics were performed with Wilcoxon rank-sum test for continuous variables (median; IQR) and Chi-square (*n*; %) for categorical variables. A multivariable linear random effects model [20] was regressed on significant predictor variables on univariable analysis ($p < 0.25$) [21], and was used to model operative time [22].

Results

Figure 2 provides a flowchart of patient selection for our study. From a total of 334 adrenalectomies performed by the two surgeons at this institution, 83 patients were identified who had unilateral retroperitoneoscopic approach and had adequate preoperative imaging for the included anthropometric measurements. Many patients were

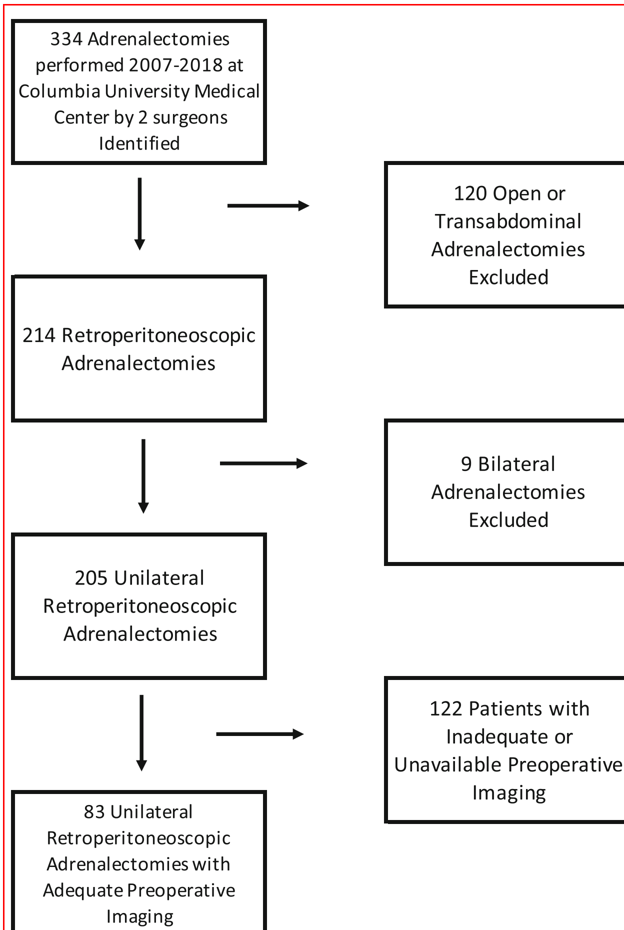

Fig. 2 Flowchart of patient selection process

excluded due to having inadequate preoperative imaging such as imaging that did not reach the hips to provide for hip diameter, hip anterior–posterior distance and therefore waist-to-hip ratio, and were therefore excluded from the study.

Patient demographics are summarized in Table 1. The majority of patients were female (n = 46; 55.4%) and white (40, 48.2%) with median age of 54 years with interquartile range (IQR) (43–63). Average BMI was 27.8 with IQR (21.2–38.6). Clinical diagnoses included 18 pheochromocytomas (23.1%), 14 cortisol secreting tumors (17.9%), 4 adrenal metastases (5.1%) and 42 other (53.8%). There were 43 left-sided tumors (51.8%) and 40 right-sided (48.2%).

Longer median operative time was significantly associated with gender, laterality of tumor, clinical diagnosis and surgeon. Male gender was associated with a longer operative time when compared to female gender (85 min IQR 72–111.5 vs. female 63 min IQR 51–79, $p < 0.01$). Right-sided tumors took longer to resect than left-sided tumors, with a median of 82 (IQR 70–96) minutes versus 64.5 (IQR 58.25–83.75) minutes ($p = 0.04$). Clinical diagnosis was significant for operative time ($p < 0.01$) with post-hoc Dunnett's test showing adrenal metastasis having a significantly longer operations (96 min IQR 976.7–120.7) when compared to non-pheochromocytoma (72.5 IQR 58.5–84.2). Longer operative time is also associated with operative surgeon with surgeon A having shorter operative time (72 IQR (59.75–93.25) vs. 85 IQR (80–94) $p < 0.01$). An interaction term between surgeon and order of operation was not significant, and therefore we only included order of operation as a main effect predictor variable. Race and tumor volume were not associated with a difference in

Table 1 Summary of patient demographics and outcomes

Demographics				Outcomes	
Patient characteristics	n (%) or median (IQR)	Median operative time and IQR (smin)	p value	Complication rate[a] (%)	p value
Gender			<0.01		0.88
Male	37 (44.6%)	85 (72–111.5)		2.7	
Female	46 (55.4%)	63 (51–79)		2.2	
Race			0.07		0.29
White	40 (48.2%)	83 (64.5–110)		5.0	
Black	6 (7.25%)	65.5 (58.25–75)		16.7	
Asian	6 (7.25%)	92 (68.5–108)		0.0	
Pacific islander	3 (3.6%)	70 (66.5–72.5)		0.0	
Unknown	28 (33.7%)	63 (53–81.5)		0.0	
Age (years)	54 (43–63)	74 (60–93)	<0.01	6.0	0.50
BMI (kg/m^2)	27.8 (21.2–38.6)		<0.01		0.92
<18.5	1 (1.2%)	120 (120–120)		0.0	
18.5–25	23 (28.4%)	73.5 (51.25–85.75)		4.3	
25–30	25 (30.9%)	65 (60–85)		4.0	
30–35	21 (25.9%)	87 (64–106.75)		0.0	
35–40	10 (12.3%)	75 (66–83.5)		0.0	
>40	1 (1.2%)	130 (130–130)		0.0	
Clinical diagnosis			<0.01		0.44
Pheochromocytoma	18 (23.1%)	72.5 (58.5–84.2)	Ref	11.1	
Cortisol secreting tumor	14 (17.9%)	61 (47.7–71.2)	0.12	0.0	
Adrenal metastasis	4 (5.1%)	96 (76.7–120.7)	<0.01	0.0	
Other	42 (53.8%)	82 (63–95)	0.28	0.0	
Side			0.04		0.14
Right	40 (48.2%)	82 (70–96)		5.0	
Left	43 (51.8%)	64.5 (58.25–83.75)		0.0	
Surgeon			<0.01		0.60
A	72 (88.9%)	72 (59.75–93.25)		2.7	
B	9 (11.1%)	85 (80–94)		0.0	

[a]Overall complication including conversion to open, blood loss requiring a transfusion, renal dysfunction, cardiopulmonary event, incisional hernia or death

operative time. Median tumor volume was 7.5cm^3 (interquartile range 1.1–19.0) but was not significant for operative time ($p = 0.85$).

Table 2 gives an overview of the anthropometric measurements on preoperative CT with median measurements and interquartile ranges. Correlation coefficient for operative time is also included.

Overall, there were two complications (complication rate 2.4%). There was one incisional hernia and one case of urinary retention. All EBL was under 100 cc, and there was no blood loss that required transfusion. Pheochromocytoma was the only diagnosis that had complications with a rate of 11.1% ($p = 0.44$). There were no differences between surgeons with regard to complication rate.

Figure 3 is a longitudinal chart graphing the sequential operation of each surgeon against the operative time taken. Each operation's sequential number was taken from the surgeon's overall experience and not just from the cases included in our study so that the data would be more representative of the true experience at the time of each operation. The sequence of the operation was significant ($p = 0.02$) with both surgeons having shorter operative times as they became more accustomed to this approach.

Table 3 outlines the multivariable linear random effects model that was regressed on significant predictor variables on univariable analysis ($p < 0.25$). On multivariable analysis, only side, order of operation and periadrenal volume retained significance ($p = 0.01$; $p = 0.02$; $p < 0.01$). Table 4 highlights the collinearity matrix of all significant univariable predictors with variance inflation factor (VIF) scores, none of which were higher than 10.

Discussion

Prior studies have detailed clinical outcome benefits from laparoscopic retroperitoneal adrenalectomy; however, there have been concerns about body habitus and anthropometric factors, and their impact on operative difficulty. This is the first study that includes these parameters while accounting for surgeon experience. Our study shows that side and periadrenal volume are the most impactful on operative time even when accounting for surgeon experience. The right adrenalectomy proves difficult with the dissection along the inferior vena cava. Periadrenal volume also increases operative time due necessitating an increased difficulty and amount of overall dissection.

Although it did not retain significance on multivariable analysis, men had a significantly longer operative time than women on univariable analysis. Men have a larger volume of periadrenal fat than women which increases operative difficulty and time. However, when controlled for periadrenal volume, the difference in operative difficulty between men and women cancels. Waist measurements including anterior to posterior diameter, area and ratio to hip similarly were significant on univariable analysis but did not retain significance on multivariable analysis. This could be explained by waist measurements being confounded by periadrenal measurements.

Although Lindeman et al.'s paper detailing the Posterior Adiposity Index (PAI) as a predictor of operative time [18] was published after data collection began for our investigation, an analogous measurement was obtained and analyzed. When included in our linear random effects model, PAI was a significant predictor of operative time ($p < 0.01$) on univariable analysis, but did not retain significance on multivariable analysis ($p = 0.81$) when side, diagnosis, surgeon experience and periadrenal volume and other variables were taken into account.

Table 2 Anthropometric measurements

	Median (interquartile range)	Correlation coefficient
Anterior perirenal (cm)	0.7 (0.4–1.1)	0.26
Posterior perirenal (cm)	0.8 (0.5–1.6)	0.34
Subcutaneous (cm)	3.5 (2.3–4.1)	0.18
Iliac to rib (cm)	8.9 (6.9–9.8)	0.11
Area of waist (cm^2)	2,550 (2,190–3,180)	0.29
Area of hip (cm^2)	2,810 (2,300–3,400)	− 0.03
Volume periadrenal (cm^3)	14.1 (5.8–37.2)	0.37
Volume non-right pyramid (cm^3)	16.7 (7.7–47.5)	0.40
Ratio of waist to hip	0.94 (0.81–1.04)	0.36
PAI (Posterior Adiposity Index)	6.34 (5.09–7.59)	0.29

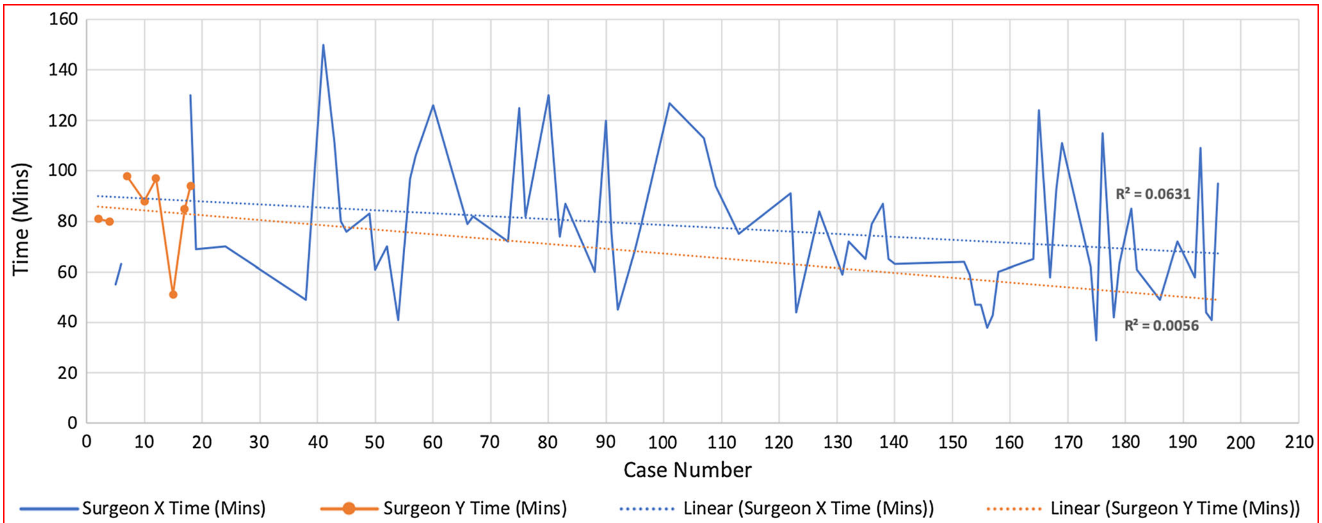

Fig. 3 Operative time by case

Table 3 Multivariable linear random effects model on operative time

Predictor variables	Multivariable analysis	
	Coefficient	*p* value
Gender	− 12.24	0.073
Diagnosis		0.048
Pheochromocytoma		Ref
Cortisol secreting	− 15.51	0.04
Adrenal metastasis	18.78	0.15
BMI	0.14	0.57
Side	14.26	<0.01
Anterior–posterior waist distance	0.032	0.815
Area of waist	− 0.00005	0.614
Ratio of waist to Hip	23.19	0.281
Periadrenal volume	0.0002	<0.01
Posterior Adiposity Index	1.9	0.811
Order of operation	− 0.09	0.016

One important, but not surprising, finding in our study is that increasing operative experience is associated with decreased length of operative time. Given that laparoscopic adrenalectomy, transabdominal or retroperitoneoscopic, is associated with a very low complication rate (as redemonstrated by our data), operative time is a commonly analyzed outcome and often is a surrogate for quality of care. As operative time is a surrogate quality measure, it is imperative to accommodate for surgeon experience, as surgeon experience directly impacts operative time.

Our study shows that BMI itself does not impact operative time when controlled for side, periadrenal fat volume, as well as index order of operation. It is important to note that there were no super-morbid obese patients in our study. Patients were selected appropriately for this approach as there are concerns of feasibility of this operation on patients who are super-morbidly obese.

Limitations to our study include that this was a retrospective analysis with low numbers. Adrenalectomy is an uncommon procedure with the retroperitoneoscopic approach being even rarer. This means that power was a limitation in our study. One factor that we were not able to account for was resident or fellow involvement. The level of assistant involvement was not documented and so was not able to be accounted for. There also may have been a difference in operative time based on time of year (directly related to changes in trainee involvement based on progression) which was unable to be measured or accounted for with this retrospective analysis. This would, especially, be impactful as the operative time used was incision time to closure of skin, and trainee involvement could greatly impact closing time as well. Additionally, there may have been variation in how circulating nurses recorded operative time, which would be unable to be accounted for in the retrospective format of our study. One other factor that was difficult if not impossible to account for in our analysis was case complexity which is likely incredibly impactful on operative time.

Despite these limitations, we still believe our study provides important insights. Retroperitoneoscopic adrenalectomy is a challenging procedure technically and so being able to appropriately select patients based on preoperative periadrenal volumes can aid in preoperative and intraoperative planning. The highest predictor of operative time is surgeon experience, but these measurements are also correlated and should be considered in

Table 4 Variance inflation factors

Variable	VIF	1/VIF
Side	1.28	0.779914
Gender	2.26	0.442592
Diagnosis		
Pheochromocytoma	1.87	0.535517
Cortisol secreting adenoma	1.72	0.581012
Adrenal metastasis	1.07	0.935812
Other	1.11	0.898006
Anthropometric measurement		
AP waist	6.22	0.16083
Area of waist	6.79	0.14719
Ratio of waist to hip	2.17	0.461067
Periadrenal volume	2.51	0.398318
Posterior Adipose Index	1.81	0.551154

patient selection, especially as surgeons are using this approach for patients with increasingly larger BMIs.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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