Int J Clin Exp Med 2018;11(7):7358-7366
www.ijcem.com /ISSN:1940-5901/IJCEM0061768

Original Article

Unplanned reoperations in neurosurgery: a single center experience

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Received July 18, 2017; Accepted December 30, 2017; Epub July 15, 2018; Published July 30, 2018

Abstract: *Objective:* The purpose of this study was to comprehensively analyze the unplanned reoperations in neurosurgery within our center and to explore potential factors associated with unplanned reoperations. *Methods:* The authors retrospectively reviewed the patients who underwent unplanned reoperations in the Department of Neurosurgery of West China Hospital of Sichuan University from May 2015 to October 2016. The patients' basic characteristics, perioperative data of the initial surgeries and reoperations, outcomes, length of stay (LOS) and hospitalization expenses were collected for analysis. Factors associated with unplanned reoperations were identified using univariate analysis and multivariate logistic regression modeling. *Results:* A total of 115 patients and 129 unplanned reoperations were included. The overall incidence of unplanned reoperations was 1.37%. The principal diseases were tumors (50.4%), aneurysms (18.3%) and vascular malformations (11.3%). The most common causes of unplanned reoperations were postoperative hemorrhage (42.6%) and postoperative hydrocephalus (25.6%). Higher age and supratentorial location were risk factors for postoperative hemorrhage. Risk factors for postoperative hydrocephalus included younger age, infratentorial location, leukocytosis and rotation of first-line doctors. Patients who underwent unplanned reoperations had poorer outcomes, longer LOS and higher hospitalization expenses. *Conclusions:* Identifying patients at a higher risk for unplanned reoperations may improve the quality of surgical care. More studies are warranted to explore the risk factors for unplanned reoperations. We recommended standard report and regular discussion on the reoperated cases. Besides, it is urgent to perform systematic root-cause analyses and to establish perioperative protocols through multidisciplinary work to reduce the frequency of unplanned reoperations.

Keywords: Reoperation, neurosurgery, complication

Introduction

Surgery accounts for the majority of inpatient adverse events, with the proportion estimated from 48% to 79% [1]. Higher incidence of surgical adverse events would result in poorer outcomes, higher costs, less efficiently used health care resources and poorer patient satisfaction [2-4]. Systematic measurements of these adverse events and prospective recording can help in quality improvement [5-7]. At present, the primary method to assess surgical quality is to review morbidity and mortality. [8-10]. However, due to the rare mortality rate and procedure-specific complications, they would not be ideal measures across all surgical specialties [11, 12].

In recent years, unplanned reoperation rate, which is a surrogate for surgical adverse events, has been suggested as a quality indicator in surgical care [11, 13]. Like surgical adverse events, unplanned reoperation has a negative impact on outcomes and costs, and may even lead to conflict between the patient and surgeon [2, 4]. Unplanned reoperation rate can be compared across departments and hospitals, and the quality of services can be improved by monitoring it [7, 11].

Unplanned reoperations were first assessed among general surgery [10]. Recently, several studies examined the use of unplanned reoperation rate in neurosurgery [2, 7, 10, 12, 14-16]. Some of them focused on a specific disease, such as tumor or unruptured intracranial aneurysms, some focused on postoperative bleeding, and some focused on children. Few studies reported department-wide neurosurgical unplanned reoperations across all diseases

and all causes in both adults and children [10]. Furthermore, research on unplanned reoperations with respect to neurosurgical procedures is scarce in China [12].

In this study, we retrospectively reviewed all the patients who underwent unplanned reoperations during a time period of 18 months in our department. We analyzed the incidence rate, causes, outcomes, and further explored potential factors associated with unplanned reoperations.

Materials and methods

Patient population and data collection

This study was approved by the Institutional Review Board of our hospital. In our hospital (tertiary), the details of the patients who undergo unplanned reoperations are required to be reported to the Medical Quality Control Office and the Department of Medical Administration. We retrospectively reviewed the reports of the patients from the Department of Neurosurgery from May 1st, 2015 to October 31st, 2016. The medical records and radiological images of these patients were also reviewed for more information. The extracted data included age, gender, admission type (index hospitalization or emergency admission), primary disease and location, preoperative blood pressure, preoperative plate count and coagulation function, preoperative white blood cell count, details of the initial surgery (elective/emergency, operation type, American Society of Anesthesiologists' ASA anaesthesia grade, operation time and blood transfusion during operation), reason of the unplanned reoperation, time interval to reoperation, details of the unplanned reoperation, discharge status (home/to rehabilitation ward/against-advice discharge/dead), length of stay (LOS) and hospitalization expenses. The information of the patients in our whole department and whole hospital during the same period was also collected: total number of neurosurgical procedures, mean LOS and mean hospitalization expenses in our department, total number of surgical procedures and the number of unplanned reoperations in our hospital.

Definitions

In this study, an unplanned reoperation was defined as an unscheduled procedure performed after the initial surgery, either during the same admission or during a readmission. A second or third unplanned reoperation following the first unplanned reoperation was also defined as an unplanned reoperation. Favorable outcomes were defined as discharged home or to the rehabilitation ward. Against-advice discharge meant that the patient or the family members gave up treatment. The rotation of first-line doctors was regarded as a potential risk factor for unplanned reoperations. The initial surgeries were categorized into "normal period group" and "rotation period group" (4-week period after the rotation of first-line doctors).

Statistical analysis

The data were summarized as mean ± standard deviations (SD) with range for continuous variables and percentage for categorical variables. Univariate binary logistic regression analysis was used to identify potential risk factors for unplanned reoperations caused by hemorrhage or hydrocephalus. Significant or near-significant factors were then tested using multivariate logistic regression models. Statistical analyses were performed using SPSS, version 24.0 (SPSS Inc., Chicago, IL, USA). Significance was determined at $p<0.05$, and p value <0.20 was considered near-significant.

Results

Our study included 115 patients who underwent unplanned reoperations. The majority of patients underwent one unplanned reoperation. Ten patients had two unplanned reoperations and two patients had three unplanned reoperations. Thus, a total of 129 unplanned reoperations were performed on them. The overall incidence of unplanned reoperations in our department was 1.37%, which was much higher than that in our whole hospital (0.37%) during the same time period.

Patient characteristics and initial surgical details

Of the 115 patients, 60 were female and 55 were male. The mean age of the patients was 46.4±1.7 years (range 0.5-83.5 years). Thirty-five (30.4%) were emergency admissions. The principal diseases were tumors (58 cases, 50.4%), aneurysms (21 cases, 18.3%) and vascular malformations (13 cases, 11.3%). Pa-

Table 1. Characteristics of the patients with two or three unplanned reoperations

No.	Sex	Age (years)	Disease	Site	Initial surgery	Reasons for reoperation	Reoperation	Surgery interval (days)	Discharge
1	F	1.2	lipoma	sacrococcygeal part	lesion excision	1st: infection 2ed: infection	1st: debridement 2ed: debridement	1st: 11 2ed: 10	home
2	F	26.0	hemangioma	left hemisphere of cerebellum	lesion excision	1st: hematoma 2ed: poor wound healing	1st: hematoma evacuation 2ed: debridement and suture	1st: 0 2ed: 40	home
3	F	26.6	WHO grade II central neurocytoma	left lateral ventricle	lesion excision	1st: hydrocephalus 2ed: drainage tube pulled out by patient accidently 3rd: hydrocephalus	1st: EVD 2ed: EVD 3rd: VP shunt	1st: 6 2ed: 9 3rd: 6	home
4	M	45.3	neurilemmoma	T3-T4	lesion excision	1st: hydrocephalus 2ed: hydrocephalus	1st: EVD 2ed: VP shunt	1st: 3 2ed: 8	home
5	F	63.9	neurilemmoma	left CPA	lesion excision	1st: hydrocephalus 2ed: swell of cerebellum	1st: EVD 2ed: excision of swelling cerebellum	1st: 1 2ed: 1	home
6	M	13.3	mixed germ cell tumor	right frontal lobe	lesion excision	1st: hydrocephalus 2ed: hydrocephalus	1st: EVD 2ed: exploration of ventricular lesion+ETV	1st: 3 2ed: 8	RW
7	M	17.1	neurilemmoma	left CPA	lesion excision	1st: hydrocephalus 2ed: hydrocephalus (1st tube occluded)	1st: EVD 2ed: EVD	1st: 1 2ed: 6	RW
8	M	46.1	atypical meningioma	right thalamus	lesion excision	1st: hematoma 2ed: hydrocephalus	1st: hematoma evacuation 2ed: EVD	1st: 12 2ed: 24	RW
9	M	50.0	pilocytic astrocytoma	fourth ventricle	lesion excision	1st: hydrocephalus 2ed: hydrocephalus	1st: EVD 2ed: VP shunt	1st: 1 2ed: 17	RW
10	M	51.5	benign meningioma	left tentorium	lesion excision	1st: hydrocephalus 2ed: swell of cerebellum	1st: EVD 2ed: excision of swelling cerebellum	1st: 1 2ed: 1	RW
11	F	63.5	hemangioma	right hemisphere of cerebellum	lesion excision	1st: hematoma 2ed: hydrocephalus	1st: hematoma evacuation 2ed: EVD	1st: 5 2ed: 1	AAD
12	M	26.3	vascular malformation	right parietal and occipital lobes, and right basal ganglion	lesion excision	1st: infection and hydrocephalus 2ed: infection and hydrocephalus 3rd: infection and hydrocephalus	1st: EVD 2ed: EVD 3rd: division of ventricular synechiae+ETV+septum pellucidum fistulation+EVD	1st: 24 2ed: 9 3rd: 9	dead

F female, M male, CPA cerebellopontine angle, EVD external ventricular drain, VP ventriculoperitoneal, ETV endoscopic third ventriculostomy, RW rehabilitation ward, AAD against-advice discharge.

tients with WHO grade I meningiomas (20 cases) and neurilemmomas (11 cases) accounted for the most tumor cases. The lesion sites included 72 supratentorial (62.6%), 36 infratentorial (31.3%), 5 intraspinal (4.3%), 1 skull lesion (0.8%) and 1 scalp lesion (0.8%). As to the initial surgeries, 14 (12.2%) were emergency surgeries. The principal operations were for excision of space-occupying lesion (68 cases, 59.1%) and aneurysm clipping (16 cases, 13.9%).

Characteristics of the reoperations

The most common causes of unplanned reoperations were postoperative hemorrhage (55 cases, 42.6%) and postoperative hydrocephalus (37 cases, 28.7%). The mean time interval between the unplanned reoperation and last surgery was 5.8±0.7 days (range 0-56 days), and 48 unplanned reoperations (37.2%) were performed within one day. The mean time interval to reoperation was 3.0±0.5 days for postoperative hemorrhage and 6.7±1.2 days for postoperative hydrocephalus. Most reoperations (113 cases, 87.6%) were emergency surgeries. The principal reoperations were hematoma evacuation (47 cases, 36.4%) and external ventricular drain (28 cases, 21.7%). Compared to the initial surgeries, the ASA anaesthesia grade, operation time and blood transfusion of the reoperations were different. The proportion of ASA grade 4-6 in the reoperations (28.4%) was much higher than that in the initial surgeries (9.5%). Eighty-one initial surgeries (62.8%) needed more than three hours to complete, while only 44 reoperations (38.3%) exceeded three hours. Nineteen percent patients needed blood transfusion during the initial surgeries and the proportion dropped to 12% for the reoperations.

Patients with two or three unplanned reoperations

The details of the 12 patients with two or three unplanned reoperations were shown in **Table 1**. The initial surgeries of all the patients were lesion excision. Half of the patients (6 cases) underwent at least two reoperations for postoperative hydrocephalus. Most of these patients (10 cases, 83.3%) had a favorable outcome, except one against-advice discharge and one dead.

Patients' outcomes

Among the 115 patients, 84 (73.0%) turned better and were discharged home (29 cases, 25.2%) or to the rehabilitation ward (55 cases, 47.8%). Twenty-four patients (19.3%) were discharged against-advice. The mortality was 5.2% (6 cases). One patient is still in hospital and has been in the neurosurgical intensive care unit (NICU) for more than one year.

The mean LOS of the 114 patients was 29.3±2.9 days (except for the patient still in hospital), which was much longer compared with the mean LOS of 10.2 days for patients in our whole department during the study period. The mean LOS was the longest for the patients discharged home (43.9 days), and was the shortest for the patients discharged against-advice (19.3 days).

Compared with the mean hospitalization expenses of 7,267 USD for the patients in our whole department, the mean hospitalization expenses of the 114 patients was 22,855± 1,356 USD (except for the patient still in hospital, 74,472 USD for herself).

The four principal diseases

The main characteristics of the patients with the four principal diseases were shown in **Table 2**. The most common reason for reoperation was all postoperative hemorrhage in patients with the four types of diseases. As to the outcome, higher rates of favorable outcome were observed in patients with WHO grade I meningioma and neurilemmoma (95% and 100%, respectively), compared to the patients with aneurysm and vascular malformation (48% and 62%, respectively). The mean hospitalization expenses were also higher in the patients with aneurysm and vascular malformation than those in the patients with WHO grade I meningioma and neurilemmoma.

The two major reasons

The main characteristics of the patients with postoperative hemorrhage and postoperative hydrocephalus were shown in **Table 3**. Around 70% patients had a favorable outcome in both groups. The mean LOS was longer and the mean hospitalization expenses were higher in the patients with postoperative hydrocephalus,

Table 2. Characteristics of the patients with the four principal diseases

Disease[a]	Initial surgeries[a]	Reasons for reoperation[a]	Reoperations[a]	Discharge[a]	Mean LOS (days)	Mean LOS after surgery (days)	Hospitalization expenses (USD)
Aneurysm-21	clipping-16	hematoma-9	DC-10	home-3	23.2±3.4[b]	16.3±3.3[b]	26,931±2,462[b]
	interventional embolization-5	cerebral infarction-8	hematoma evacuation-5	RW-7			
		hydrocephalus-2	hematoma evacuation+DC-4	AAD-9			
		brain swell-2	EVD-2	dead-1			
				still in hospital-1			
WHO grade I meningioma-20	excision-20	hematoma-13	hematoma evacuation-13	home-5	21.0±2.3	14.0±2.0	16,750±1,605
		hydrocephalus-3	EVD-3	RW-14			
		brain swell-2	decompression-2	AAD-1			
		brain hernia-1	DC-1				
		stuck ICP probe-1	removal of probe-1				
Vascular malformation-13	excision-12	hematoma-5	hematoma evacuation-5	home-3	30.8±5.5	15.6±4.2	27,785±5,352
	interventional embolization-1	hydrocephalus-3	EVD-3	RW-5			
		infection-1	wound cavity drainage-1	AAD-3			
		CSF leak-1	CSF leak repair-1	dead-2			
		brain hernia-1	DC-1				
		abscess-1	removal of abscess-1				
		stuck ICP probe-1	removal of probe-1				
Neurilemmoma-11	excision-11	hematoma-6	hematoma evacuation-6	home-3	22.6±3.5	15.3±3.4	18,423±3,045
		hydrocephalus-3	EVD-3	RW-8			
		brain swell-1	decompression-1				
		drainage tube fracture-1	removal of drainage tube-1				

ICP intracranial pressure, CSF cerebrospinal fluid, DC decompressive craniectomy, EVD external ventricular drain, RW rehabilitation ward, AAD against-advice discharge, LOS length of stay, USD US dollar. [a]with the number of cases behind. [b]calculated without the patient still in hospital.

Table 3. Characteristics of the patients reoperated for postoperative hemorrhage and postoperative hydrocephalus

Reason for reoperation[a]	Reoperations[a]	Dischargea[a]	Mean LOS (days)[b]	Mean LOS after surgery (days)[b]	Hospitalization expenses (USD)[b]
Hematoma-55	hematoma evacuation-47	home-10	25.0±2.3	16.9±2.0	22,205±1,786
	hematoma evacuation+DC-7	RW-30			
	hematoma evacuation+cortical electrode removal+epileptogenic focus resection-1	AAD-12			
		dead-3			
Hydrocephalus-29[c]	EVD-28	home-8	38.7±10.3	26.0±10.6	26,549±3,590
	VP shunt-6	RW-12			
	exploration of ventricular lesion+ETV-1	AAD-8			
	right ventricle fistulation+decompression-1	dead-1			
	division of ventricular synechiae+ETV+septum pellucidum fistulation+EVD-1				

DC decompressive craniectomy, EVD external ventricular drain, VP ventriculoperitoneal, ETV endoscopic third ventriculostomy, RW rehabilitation ward, AAD against-advice discharge, LOS length of stay, USD US dollar. [a]with the number of cases behind. [b]two patients both underwent the 1st unplanned reoperation for postoperative hemorrhage and underwent the 2ed unplanned reoperation for postoperative hydrocephalus, thus they were excluded in the calculation of these data. [c]29 patients with 37 reoperations for hydrocephalus

compared to the patients with postoperative hemorrhage.

Factors associated with postoperative hemorrhage or postoperative hydrocephalus

On multivariate analysis, several factors associated with postoperative hemorrhage or postoperative hydrocephalus were identified (**Table 4**). Higher age was a risk factor for postoperative hemorrhage, but was a favorable factor for postoperative hydrocephalus. Favorable factors for postoperative hemorrhage included aneurysm disease, infratentorial location and leukocytosis. Risk factors for postoperative hydrocephalus included infratentorial location, leukocytosis and rotation of first-line doctors.

Discussion

In this study, the rate of unplanned reoperations for all causes was 1.37% in our department. Tumors and aneurysms constituted most primary diseases. The most common causes of unplanned reoperations were postoperative hemorrhage and postoperative hydrocephalus. In multivariate analysis, several favorable factors and risk factors were identified to be associated with postoperative hemorrhage or postoperative hydrocephalus. The patients who underwent unplanned reoperations had poorer outcomes, longer LOS and higher hospitalization expenses.

The rate of unplanned reoperations in neurosurgery varied depending on the definition, difference in case series, and detecting method among different hospitals [7, 10, 14]. McLaughlin *et al*. reported that the incidence of unplanned reoperations within 7 days of the index surgery was 2.6% [10]. Mukerji *et al*. reported that the unplanned reoperation rate was 28% in pediatric neurosurgery [7]. Dasenbrock *et al*. reported an unplanned reoperation rate of 3.1% among patients who underwent cranial tumor resection extracted from the prospective National Surgical Quality Improvement Program (NSQIP) registry (2012-2014) [17]. With the same standard in our hospital, the unplanned reoperation rate in the neurosurgical department was much higher than that in our whole hospital during the same period (1.37% *vs*. 0.37%), demonstrating neurosurgical procedures to be at a relatively higher risk.

Table 4. Variables significantly associated with postoperative hemorrhage and postoperative hydrocephalus on multivariate logistic regression analysis

Variable	OR (95% CI)	*p* value
Factors associated with postoperative hemorrhage		
Age (per 10-year increase)	1.63 (1.18-2.25)	0.003
Aneurysm (vs diseases except tumors and vascular malformation)	0.12 (0.02-0.71)	0.020
Infratentorial location (vs supratentorial)	0.24 (0.08-0.75)	0.014
Leucocytosis	0.16 (0.03-0.72)	0.017
Factors associated with postoperative hydrocephalus		
Age (per 10-year increase)	0.69 (0.50-0.95)	0.024
Infratentorial location (vs supratentorial)	5.45 (1.42-20.92)	0.014
Leucocytosis	11.42 (1.86-70.04)	0.008
Rotation of first-line doctors	2.97 (1.01-8.73)	0.048

OR oddo ratio, CI confidence interval.

In McLaughlin's case series, shunt-related disease and intracranial tumor accounted for most of their cases, which is different from our series [10]. In that study, a larger proportion of cases were pediatric cases (about 30%), which may explain the discrepancy. Accordingly, the most common indication for early unplanned reoperations in that study was shunt failure, followed by postoperative bleeding. In another two studies on pediatric neurosurgery, the most common cause of unplanned reoperations was also shunt failure [7, 15]. In two studies investigating unplanned reoperations after removal of intracranial tumors, postoperative hemorrhage was the most common cause [17, 18]. Park *et al.* found that compromised distal blood flow was the most common reason for an unplanned reoperation in patients with unruptured intracranial aneurysms [14, 16]. In our study, the most common cause for unplanned reoperations in patients with intracranial aneurysms was postoperative bleeding. One possible explanation might be that most of our patients were with ruptured intracranial aneurysms. From the published literature and our study, we can roughly conclude that, the most common causes for unplanned reoperations are shunt failure and postoperative bleeding after pediatric neurosurgery and removal of intracranial tumors respectively, and that the most common reasons for unplanned reoperations are postoperative bleeding and compromised distal blood flow in patients with aneurysms.

As to the factors associated with postoperative hemorrhage or postoperative hydrocephalus, several were identified on multivariate analysis. Our study found that, with the age increasing by 10 years, patients have a 1.6 times higher risk for postoperative hemorrhage. Previous studies did not identify age as a risk factor for postoperative hemorrhage after craniotomy [2, 12]. But studies focusing on other surgeries, like tonsillectomy, found higher age to be a risk factor for postoperative hemorrhage [19, 20]. We also found that aneurysm disease, infratentorial location and leukocytosis were favorable factors for postoperative hemorrhage. Still, previous studies did not identify aneurysm disease and infratentorial location as associated factors for postoperative hemorrhage [2, 12]. Dasenbrock *et al*. found that leukocytosis was a predictor of reoperation for hematoma, which was contrary to our finding. With regard to postoperative hydrocephalus, risk factors included younger age, infratentorial location, leukocytosis and rotation of first-line doctors. It is easy to understand infratentorial location as a risk factor for postoperative hydrocephalus, since infratentorial occupation and surgical procedure could result in obstructive hydrocephalus by interfering normal cerebrospinal fluid pathway [21]. Lin *et al*. found that younger patients with posterior fossa tumors were at higher risk for the development of persistent hydrocephalus, which was consistent with our results [21]. Despite the present findings, more studies are warranted to explore risk factors for postoperative hemorrhage and postoperative hydrocephalus.

Quite few studies investigated the postoperative outcomes, LOS and hospitalization expenses in patients who underwent unplanned reop-

erations [10, 18]. In our study, without surprise, we found that patients who underwent unplanned reoperations had relatively poorer outcomes, longer LOS and higher hospitalization expenses. Thus, we suggest the rate of unplanned reoperations be a quality indicator in surgical care. Besides, the rate of unplanned reoperations is easy to track and may be suitable for comparison between departments and hospitals [10]. However, there are some limitations for the use of the rate of unplanned reoperations as a quality indicator at present. Firstly, under some circumstances, the rate of unplanned reoperations may reflects the severity or the complexity of the underlying condition and the related initial procedure, other than suboptimal initial surgery [10]. Furthermore, the difference in definitions, detecting methods and practices may influence the calculation of the rates [10]. So we are in favor of McLaughlin's suggestions to explore an adjusted reoperation rate and to adopt several other complementary indicators with a weighted value.

The ultimate aim to use unplanned reoperation rate as a quality indicator is to reduce the rate of unplanned reoperations. In our hospital, the surgeons are required to report the details of every patient who underwent unplanned reoperations to the Medical Quality Control Office and the Department of Medical Administration, with the intent of improving healthcare quality and preparing to deal with potential conflict between the patient and surgeon given the tense relationship between doctors and patients in China. Also, our department began to discuss the cases that underwent unplanned reoperations after the weekly mortality conference, which was considered useful to decrease unplanned reoperation rates [1]. Hence, we recommend standard report and regular discussion on the cases that underwent unplanned reoperations. Moreover, it is crucial to perform systematic root-cause analyses and to establish perioperative protocols by the multidisciplinary workforces [10].

There were several limitations in our study. Firstly, it was a retrospective study and the included cases were from a single hospital, which can lessen the generalizability of this type analysis. In addition, this study included a relatively small sample size. Also, in some cases, some data was missing. Besides, the surgeons' varying practices may reduce the strength of the risk model. And we did not follow up the patients after they were discharged.

The rate of unplanned reoperations was relatively higher in neurosurgical patients. The most common causes of unplanned reoperations were postoperative hemorrhage and postoperative hydrocephalus in our center. Identifying patients at a higher risk for unplanned reoperations may improve the quality of surgical care. However, more studies are warranted to explore the risk factors for an unplanned reoperation. The patients who underwent unplanned reoperations had poorer outcomes, longer LOS and higher hospitalization expenses, suggesting the necessity to monitor the rate of unplanned reoperations. But the rate of unplanned reoperations as a quality indicator is still open to discuss. Moreover, we recommend standard report and regular discussion on the reoperated cases, and it is urgent to perform systematic root-cause analyses and to establish perioperative protocols through multidisciplinary work to reduce the frequency of unplanned reoperations.

Disclosure of conflict of interest

None.

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