The Effect of Selective Renal Parenchymal Clamping during Laparoscopic Partial Nephrectomy on Early Postoperative Renal Function: A Preliminary Report

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Purpose: A major concern when performing laparoscopic partial nephrectomy (LPN) is potential postoperative renal dysfunction. The objective of this study was to compare the effects of LPN with selective renal parenchymal clamping (SRPC) (LPNSRPC) and LPN using microwave tissue coagulation (MTC) (LPNMTC) on postoperative renal function.

Materials and Methods: This study included 12 patients (5 men and 7 women) who underwent LPNSRPC (n = 6) or LPNMTC (n = 6) for exophytic tumors. Renal scanning with technetium-99m diethylenetriaminepentaacetic acid (Tc-99m DTPA) was performed preoperatively and postoperatively at 1 month in all patients.

Results: The mean tumor size, surgical duration, and intraoperative blood loss were similar in both groups. In the LPNMTC group, although not significant, the mean postoperative glomerular filtration rate (GFR) values in the affected kidneys were decreased compared to the preoperative values. When evaluating the affected renal function by split function (SF), the mean postoperative SF in the affected kidneys was significantly decreased compared to the preoperative value. In the LPNSRPC group, the mean postoperative GFR and SF in the affected kidneys were not significantly changed compared with the preoperative values

Conclusion: Our preliminary experience demonstrates that LPNSRPC facilitates maximal nephron-sparing surgery without collateral thermal damage causing renal impairment.

Keywords: nephrectomy; methods; laparoscopy; blood loss; pilot projects; carcinoma; renal cell; kidney neoplasms; surgery; treatment outcome.

INTRODUCTION

Partial nephrectomy (PN) is recognized as a standard of care for localized small renal masses.[1] Recently, laparoscopic partial nephrectomy (LPN) has been shown to have equivalent oncological outcomes and improved morbidity compared to the open technique.[2] As a promising minimally invasive nephron-sparing surgery, LPN is gaining popularity in the treatment of select renal tumors. Furthermore, renal function appears to have a high effect on non-cancer-related mortality, and another major concern of LPN is maximum preservation of residual renal function.[3] In particular, when applying LPN to a growing number of patients in an aging cohort with a high prevalence of preoperative latent or apparent chronic renal insufficiency, postoperative renal function should be considered in all treatment decisions.[4] However, to date, no LPN satisfies all the criteria for clinical practice.

Recently, Simon and colleagues reported a novel technique of selective clamping to establish regional ischemia in LPN, using the laparoscopic Simon clamp (Aesculap AG, Tuttlingen, Germany).[5] The laparoscopic Simon clamp is newly developed and includes a standard locking ratchet handle and an open jaw diameter of 70 mm. The clamp can be placed along the renal parenchyma immediately surrounding the renal mass, thus creating regional ischemia and limiting injury to the preserved portion of the kidney. LPN with selective renal parenchymal clamping (LPNSRPC) using the laparoscopic Simon clamp may thus minimize potential injury to the unaffected portion of the kidney. However, its effect on renal function remains unknown. The main objective of this study was to evaluate the effect of LPNSRPC on postoperative renal function using technetium-99m diethylenetriaminepentaacetic acid (Tc-99m DTPA) scanning. As the majority of patients who undergo LPN have a functioning contralateral kidney, assessment of postoperative creatinine levels to determine the effect of LPN on renal function is equivocal, since serum creatinine conveys the total renal function, which would be affected by the contralateral kidney. To evaluate the postoperative function of the affected kidney separately from the non-affected kidney is important to examine the specific utility of LPN. The Tc-99m DTPA renography is a commonly accepted and simple method for measurement of individual renal function. It provides notable information such as quantitative individual renal function and pathophysiologic changes of the kidney.[6] Moreover, calculation of SF on the basis of renal scan shows the functions of each kidney separately and thus more accurately reflects the influence of surgery on the affected kidney.[7] To the best of our knowledge, this is the first report to evaluate the effect of LPNSRPC on renal function. We also compared the changes in renal function between LPNSRPC and LPN using microwave tissue coagulation (MTC) (LPNMTC).

MATERIALS AND METHODS

Study Subjects

From October 2010, 12 consecutive patients (5 men and 7 women; mean age 62.8 ± 13.6 years; range 36-77 years) were enrolled in this study. Six patients who were undergoing LPNSRPC were compared with 6 patients who were undergoing LPNMTC. All patients had undergone preoperative spiral computed tomography (CT) with 3-dimensional reconstruction or magnetic resonance imaging (MRI) to precisely delineate the renal mass. The complexity of the renal tumor was classified using the R.E.N.A.L. nephrometry scoring system.[8] The presence of peripherally located, solitary, small renal tumors was the operative indication for LPNSRPC. In LPNMTC, in order to avoid unexpected thermal damage to the collecting system, operative indications were exophytic renal tumors with adequate intervening renal parenchyma as far as the renal collecting system (< 10 mm). Table 1 shows the preoperative patient characteristics and renal tumor data. LPNSRPC patients were generally younger than LPNMTC patients, but the difference was not statistically significant ($P = .200$). There was no significant difference in tumor diameter and nephrometry score seen between the LPNSRPC and LPNMTC groups (P = .878 and .614, respectively). In the LPNSRPC group, there was 1 case of the imperative case.

We prospectively evaluated the effects on renal function using Tc-99m DTPA scanning preoperatively and postoperatively at 1 month in all patients. Split function (SF) was calculated from renograms. All results are expressed as mean and SD. Statistical significance was determined using the Wilcoxon signed-rank test between preoperative and postoperative renal values. A P value of < .05 was considered statistically significant.

LPNSRPC Surgical Technique

After administration of general anesthesia, the patient was placed in the lateral decubitus position. Both transperitoneal and retroperitoneal approaches were used according to the

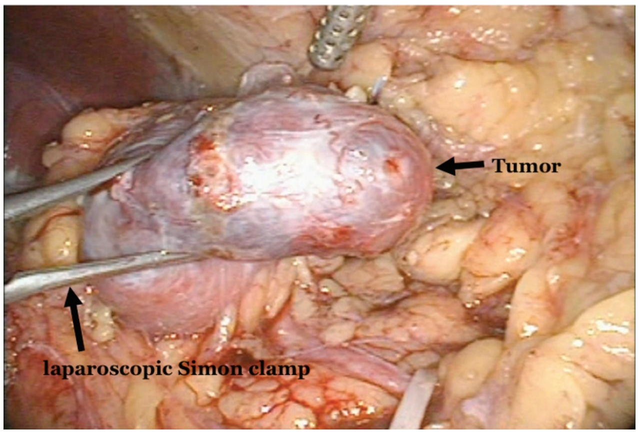

Figure 1. The laparoscopic Simon clamp was placed at a distance from the tumor edge.

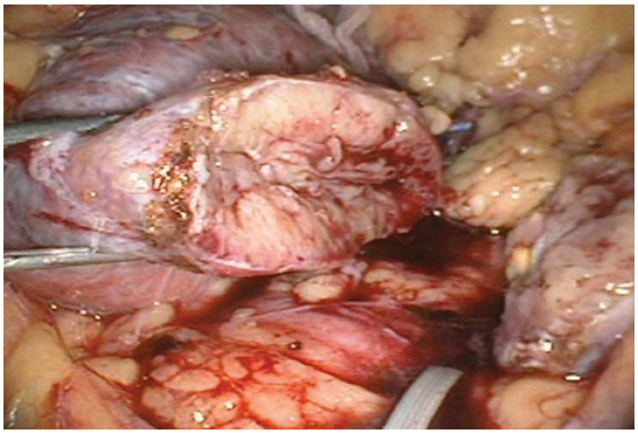

Figure 2. The resection of the tumor could easily be performed in a nearly bloodless operative field.

surgeon's discretion. At first, the kidney was dissected circumferentially and fully mobilized. The renal pedicle was not routinely dissected. After incising the Gerota's fascia to expose the renal mass, the laparoscopic ultrasonography using a 5-10 MHz flexible laparoscopic transducer (Aloka, Wallingford, CT, USA) was performed to identify the tumor location and the surgical margins. Then, 12-mm ports were placed in the ideal site to clamp the renal parenchyma. Using electrocautery scissors, the incision line was marked circumferentially approximately 1 cm from the tumor margins on the renal capsule. The laparoscopic Simon clamp was introduced through the 12-mm port to allow for closure, and it was locked in place along the tumor margin in order to create regional ischemia (Figure 1). Because the kidney was fully mobilized, once the Simon clamp was closed, it allowed for rotation of the kidney, thus providing optimal tumor visualization and facilitating tumor excision. The preserved portion of the kidney was perfused normally; therefore, the tumor could be removed without any hurry or fear of renal ischemia. The Simon clamp provided a uniform and constant pressure over the length of the jaws, permitting cold excision to be performed in a nearly bloodless field (Figure 2). After complete tumor excision, biopsy specimens from the tumor bed were sent for frozen-section study. The jaw pressure was then temporarily reduced to better visualize the bleeding site, which was then cauterized by bipolar electrocautery. If necessary, ongoing bleeding from the injured vessels was repaired using figure-of-8 sutures with 4-0 Vicryl. After achieving good hemostasis, the Simon clamp was removed. The presence of urine leakage was investigated by injecting indigotindisulfonate sodium intravenously. If entry into the collecting system was noted, intracorporeal freehand suture repair of the pelvicalyceal system was performed. Parenchymal sutures using 2-0 Vicryl sutures on a small half-circle (SH) needle were placed for cross-compression along the defect. Rolled Surgicel bolsters were then applied to the tumor bed, and the pledgeted parenchymal sutures were tied down across the bolsters to provide additional compressive hemostasis. The tumor was placed in an endoscopic-bag device and removed. A drain was subsequently placed, and the port sites were closed in the routine fashion.

LPNMTC Surgical Technique

Both transperitoneal and retroperitoneal approaches were used according to the surgeon's discretion. After obtaining tumor exposure, through a 5-mm port, a laparoscopic MTC probe (Microtaze OT-110M, Aswell Co., Osaka, Japan) was introduced. The MTC bends at its distal near-object end and causes thermal coagulation of tissues using microwave energy (2,459 MHz). This energy is transmitted from a generator through a coaxial cable to a probe, which consists of a hand piece and a needle-like electrode. The rapid oscillation of water particles caused by microwaves results in a high temperature, inducing cone-shaped tissue coagulation around the needle that is 7-10 mm in width without any carbonization. In LPN, MTC was applied peripherally to the healthy parenchyma surrounding the tumor with circumferential punctures, producing coagulation of a conical-shaped portion of tissue. Subsequently, the base of the tumor was resected using a

Table 1. preoperative patient characteristics and renal tumor data.

	Age	Sex	Side	Tumor Size (mm)	Nephrometry Score	Approach	Pathology
LPNMTC							
1	79	M	Lt	20	4	T	CCC
2	81	M	Lt	25	6	R	CCC
3	59	M	Rt	18	7	T	CCC
4	49	M	Rt	25	5	T	Chromophobe RCC
5	68	M	Rt	23	6	R	CCC
Mean ± SD	68.0 ± 12.2			21.8 ± 0.2	5.83±1.16		
LPNSRPC							
6	49	F	Lt	25	6	R	Hemorrhagic renal cyst
7	36	F	Lt	20	7	T	CCC
8	62	M	Lt	23	5	T	CCC
9	77	F	Lt	26	4	T	CCC
10	62	F	Lt	21	6	T	Papillary RCC
11	60	F	Lt	14	5	T	CCC
Mean ± SD	57.7 ± 13.9			21.5 ± 4.3	5.60 ± 1.14		

Keys: LPNMTC, laparoscopic partial nephrectomy using microwave tissue coagulation; LPNSRPC, laparoscopic partial nephrectomy with selective renal parenchymal clamping; T, transperitoneal; R, retroperitoneal; CCC, clear cell carcinoma; RCC, renal cell carcinoma; Lt, left; Rt, right; M, male; F, female.

combination of conventional 5-mm laparoscopic scissors and blunt dissection with a laparoscopic aspirator without clamping the renal pedicle. After complete tumor excision, biopsies from the tumor bed were sent for frozen-section study. The presence of urine leakage was investigated by injecting indigotindisulfonate sodium intravenously. After confirming complete hemostasis and clear margins, the specimen was placed in the laparoscopic bag and retrieved through the abdominal incision. In LPNMTC, the application of bolster, sealant, or parenchymal stitches was not necessary.

RESULTS

Table 2 shows surgical outcomes for patients who underwent LPNSRPC and LPNMTC. Both LPNSRPC and LPNMTC were successful in all patients, and conversion to open surgery or ischemic LPN was not required. There were no significant differences in the mean operative time, mean blood loss and mean Hb decrease. In the LPNSRPC group, the mean selective clamping time was 48.8 ± 11.3 min (44-59 min). All patients had negative surgical margins. Postoperative complications such as delayed hemorrhage, arteriovenous fistula, and urinary leaks did not develop in any of the patients.

Table 3 shows the perioperative renal function data. In both groups, the mean postoperative creatinine did not significantly differ from the preoperative values. None of the patients developed acute renal failure during the postoperative period. In both groups, the mean postoperative glomerular filtration rate (GFR) of both kidneys calculated from the renal scan was not significantly changed compared to the preoperative values.

In the LPNSRPC group, the mean postoperative GFR values in the affected kidneys did not significantly differ from the preoperative values (41.4 ± 18.5 mL/min vs. 38.7 ± 17.7 mL/min, $P = .562$). When evaluating each kidney separately using the renal scan, SF more accurately reflected the effect of surgery on the affected kidney.[7] The mean postoperative SF in the affected kidney was not significantly decreased compared to the preoperative value (48.8 ± 9.8% vs. 51.9 ± 5.3%, $P = .312$). In addition, mean postoperative SF in the non-affected kidney was not significantly changed compared with the preoperative value (48.0 ± 5.3% vs. 51.2 ± 9.8%, $P = .311$). In the LPNMTC group, although not significant, the mean postoperative GFR values in the affected kidneys calculated from the renal scans were reduced as compared to the preoperative values (29.6 ± 8.8 mL/min vs. 36.8 ± 10.8 mL/min, $P = .093$). In the affected kidneys, mean postopera-

Table 2. The surgical outcomes.

	LPNMTC (n = 6)	PNSRPC (n = 6)	*P*
Mean operative time (min)	209.1 ± 73.3 (105-326)	230.6 ± 38.9 (179-270)	.540
Mean blood loss (mL)	26.6 ± 60.5 (0-150)	50.0 ± 45.1 (0-100)	.84
Mean Hb decrease (g/dL)	0.5 ± 1.7 (0.1-2.6)	1.3 ± 0.7 (0.1-2.0)	.48

Keys: LPNMTC, laparoscopic partial nephrectomy using microwave tissue coagulation; LPNSRPC, laparoscopic partial nephrectomy with selective renal parenchymal clamping; Hb, hemoglobin.

tive SF values were significantly decreased compared to the preoperative values (39.7 ± 6.5% vs. 48.4 ± 4.9%, $P < .05$). On the other hand, mean postoperative SF in the non-affected kidney was significantly increased compared with the preoperative value (60.3 ± 6.5% vs. 51.3 ± 4.5%, $P < .05$).

Mean follow-ups for LPNSRPC and LPNMTC were 14.5 ± 9.3 and 17.2 ± 4.8 months, respectively ($P = .568$). Postoperative CT was performed to screen for any recurrence every 6 months. However, no patient demonstrated local recurrence or distant metastasis during the follow-up period. In the LPNSRPC group, postoperative CT did not show the bands of non-enhancing renal tissue along the surgical margins. However, in the LPNMTC group, postoperative CT showed bands of non-enhancing heat-damaged renal tissue measuring 5 to 10 mm in width along the surgical margins.

DISCUSSION

As LPN gains widespread acceptance, there is a great need for a novel surgical technique that is reliable and provides bloodless resection of the renal parenchyma without damaging the residual renal tissue. There have traditionally been 3 different technical strategies for LPN.

The complete renal ischemic technique involves clamping the renal vessels. However, a major concern is the duration of renal ischemia after hilar clamping, which generally requires 20-30 min. Since this technique is very complex, including complete tumor resection, ensuring hemostasis in the renal parenchyma and intracorporeal freehand suture repair of the pelvicalyceal system and approximation of the renal parenchyma, it may not always be easy to perform LPN within the limited warm ischemia time. It has been reported that if the warm ischemia time is prolonged during LPN, the functional damage to the affected kidney is progressive and can be irreversible.[9]

In the non-ischemic technique, a variety of energy sources may be used as an adjunctive measure to minimize hemorrhage, including ultrasonic shears,[10] water-jet dissector,[11] diode laser,[12] floating-ball radiofrequency dissector[13] and radiofrequency coagulation.[14] Resection of the tumor without inducing ischemia is feasible in small and peripherally located renal masses. However, it can be difficult to obtain adequate hemostasis and another possible major drawback is collateral thermal damage to surrounding structures due to excessive burning or charring of the tissue.

LPNSRPC permits normal blood perfusion of the unclamped kidney during LPN. Thus, a major portion of the kidney is spared from ischemia, which theoretically prevents the inherent problem of ischemic damage. However, LPNSRPC's effect on renal function is not well known and requires further studies.[5,15,16]

In the LPNSRPC group, GFR and SF in the affected kidney were not significantly different postoperatively according to renal scanning. Postoperative CT in the LPNSRPC group did not show bands of non-enhancing renal tissue along the surgical margins, as opposed to in the LPNMTC group. Furthermore, cold excision can be performed in a bloodless operative field using this technique. Cold excision may minimize collateral thermal damage to the surrounding structures. Moreover, during hemostasis, the jaw pressure can be temporarily reduced to better visualize the bleeding site, which might prevent excessive burning or charring of the tissue. The Simon clamp provides uniform and constant pressure over the length of the jaws and is therefore unlikely to crush the renal parenchyma. Although the clinical significance of frozen-section analysis to evaluate resection margins during PN is controversial, we routinely performed intraoperative pathological consultation to ensure that we achieved negative margins. Therefore, the mean selective clamping time,

Table 3. Preoperative and postoperative renal function data of LPNSRPC and LPNMTC.

Variables	LPNMTC (n = 6)	*P*	LPNSRPC (n = 6)	*P*
Mean serum creatinine (mg/dL)		.732*		
Preoperative	0.88 ± 0.16 (0.7-1.1)		0.96 ± 0.91 (0.5-2.8)	
		.750**		.250**
Postoperative	0.92 ± 0.21 (0.8-1.3)			
		.676*		
Renal Scan data				
Total Kidney		.984*		
Mean preoperative GFR	77.0 ± 25.7 (48.3-111.8)		77.3 ± 37.9 (14.5-124.3)	
		.843**		.062**
Mean postoperative GFR	74.9 ± 21.0 (50.7-102.8)		90.6 ± 55.7 (17.7-137.5)	
		.424*		
The affected kidney				
Mean preoperative GFR	36.8 ± 10.8 (25.2-51.8)		38.7 ± 17.7 (8.9-9.0)	
		.093**		.562**
Mean postoperative GFR	29.6 ± 8.8 (16.5-40.2)		41.4 ± 18.5 (11.9-61.1)	
		.191*		
		.268*		
Mean preoperative SF	48.4 ± 4.9 (38.8-52.1)		51.9 ± 5.3 (47.5-61.4)	
		< .05**		.312
Mean postoperative SF	39.7 ± 6.5 (31.8-47.8)		48.8 ± 9.8 (43.4-67.1)	
		.089*		
The non-affected kidney		.891*		
Mean preoperative GFR	40.1 ± 16.3 (23.1-16.3)		38.6 ± 20.4 (5.6-65.3)	
		.218**		< .05
Mean postoperative GFR	45.2 ± 13.9 (29.8-62.6)		48.3 ± 23.7 (5.8-77.8)	
		.793*		
		.274*		
Mean preoperative SF	51.3 ± 4.5 (47.9-60.2)		48.0 ± 5.3 (38.6-53.2)	
		< .05**		.311
Mean postoperative SF	60.3 ± 6.5 (52.2-68.2)		51.2 ± 9.8 (32.9-61.1)	
		.089*		

Keys: LPNMTC, laparoscopic partial nephrectomy using microwave tissue coagulation; LPNSRPC, laparoscopic partial nephrectomy with selective renal parenchymal clamping; GFR, glomerular filtration rate; SF, split function.
* LPNMTC vs. LPNSRPC.
** Preoperative vs. postoperative.

which included pathological consultation of a biopsy taken from the tumor bed, was relatively prolonged in comparison to other clinical reports of LPNSRPC.[16] Our study findings indicated that prolonged parenchymal clamping does not impair the postoperative renal function of the affected kidney. Therefore, our preliminary results demonstrated that LPNSRPC preserved the maximum renal function of the affected kidney. In particular, LPNSRPC would be preferable for patients with pre-existing renal impairment and elderly patients. Additional studies, including larger cohorts, are needed to support our results.

In Japan, MTC is widely used in non-ischemic LPN.[17,18] In our series, SF in the affected kidneys of the LPNMTC group were significantly decreased postoperatively, according to the renal scan. In addition, postoperative CT showed bands of non-enhancing heat-damaged renal tissue measuring 5 to 10 mm in width along the surgical margins. Nanri and colleagues suggested that renal damage induced by MTC comprises not only necrosis but also apoptotic changes. When performing the LPNMTC, it must be considered that renal thermal damage caused by MTC may spread beyond the surgeon's expectations.[19] On the other hand, SF in the non-affected kidney was significantly increased. Therefore, the renal function of the non-affected kidney might compensate for dysfunction on the affected kidney, postoperatively. Furthermore, a tumor in contact with the collecting system would be unresectable using this technique, because suturing the renal pelvic mucosa can be difficult after coagulation using the MTC. LPNMTC can be one of the useful modalities for the treatment of renal tumor because of its technical feasibility and adequate hemostasis. However, the surgeon must bear in mind that the MTC could cause heat-induced apoptosis over unexpectedly wide area.

With the exception of clamping the renal artery, the remaining surgical procedure of the LPNSRPC is similar to LPN with ischemia, including complete resection of the renal tumor, hemostasis from the renal parenchyma, and intracorporeal freehand suture repair of the pelvicalyceal system and approximation of the renal parenchyma. We recommend that LPNSRPC should be performed by highly experience surgeons with skills in laparoscopic suture. In comparison with LPN with ischemia, the Simon clamp grasps the entire kidney, and therefore, it is necessary to fully mobilize the kidney even within the confines of the limited space. The direction and angle of the kidney could be easily changed in a timely manner, thus facilitating precise tumor excision and intracorporeal freehand suture without any hurry or fear of renal ischemia.

LPNSRPC has several limitations. First, this technique cannot be applied to central or hilar tumors because of the impossibility of placing the clamp. This technique is better suited for polar tumors or small exophytic tumors located on the lateral convexity of the kidney where some degree of ischemia occurs in the normal tissue also. Second, incomplete regional ischemia may cause excessive bleeding during LPN. Therefore, special consideration should be given to the ideal trocar location for clamp placement to minimize ischemic damage during LPN. Viprakasit and colleagues reported that incomplete clamp compression at the distal aspect in 3 cases resulted in excessive bleeding and decreased visualization, necessitating parenchymal clamp removal and placement of a central hilar clamp to complete the procedure.[16] Keeping the renal pedicle with vessel tape is recommended for safe completion of LPNSRPC, especially during the learning curve. It allows rapid application of laparoscopic bulldog clamps if bleeding should preclude safe LPNSRPC. Flexibility with regard to the conversion to LPN with ischemia is necessary in cases with difficulty in complete clamp compression or unmanageable bleeding. Careful anatomical evaluation of the lesion is essential for operative success. Third, our study has a small number of patients, and this is a limitation for this study. The present study would have been enhanced by a larger series of patients to demonstrably prove the efficacy of this technique and its advantages, including reduced bleeding, maximum preservation of renal function in the affected kidney, and reduced operative time. Although we are encouraged by the preliminary findings of our experience, it was only assessed the superiority of LPNSRPC when compared with LPNMTC in early postoperative period. Recently, off-clamp,[20] or zero-ischemia approach to LPN[21] has been a proposed means of preserving global renal function by preventing ischemia to normal renal parenchyma. Further studies, in addition to a comparison of other LPN technique, such as zero-ischemia approach to LPN, are necessary to delineate what, if any specific advantages may lie with the LPNSRPC.

CONCLUSION

In this study, we describe our experience with LPN using the laparoscopic Simon clamp to induce selective regional ischemia, without renal hilar clamping, and Tc-99m DTPA scanning to compare preoperative and postoperative renal function. In carefully selected patients with tumors in ideal locations for LPNSRPC, we recommend this non-ischemic technique for maximum nephron-sparing surgery.

CONFLICT OF INTEREST

None declared.

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