Accuracy of Ultrasound-guided Nerve Blocks of the Cervical Zygapophysial Joints

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ABSTRACT

Background: Cervical zygapophysial joint nerve blocks typically are performed with fluoroscopic needle guidance. Descriptions of ultrasound-guided block of these nerves are available, but only one small study compared ultrasound with fluoroscopy, and only for the third occipital nerve. To evaluate the potential usefulness of ultrasound-guidance in clinical practice, studies that determine the accuracy of this technique using a validated control are essential. The aim of this study was to determine the accuracy of ultrasound-guided nerve blocks of the cervical zygapophysial joints using fluoroscopy as control.

Methods: Sixty volunteers were studied. Ultrasound-imaging was used to place the needle to the bony target of cervical zygapophysial joint nerve blocks. The levels of needle placement were determined randomly (three levels per volunteer). After ultrasound-guided needle placement and application of 0.2 ml contrast dye, fluoroscopic imaging was performed for later evaluation by a blinded pain physician and considered as gold standard. Raw agreement, chance-corrected agreement κ, and chance-independent agreement Φ between the ultrasound-guided placement and the assessment using fluoroscopy were calculated to quantify accuracy.

Results: One hundred eighty needles were placed in 60 volunteers. Raw agreement was 87% (95% CI 81–91%), κ was 0.74 (0.64–0.83), and Φ 0.99 (0.99–0.99). Accuracy varied significantly between the different cervical nerves: it was low for the C7 medial branch, whereas all other levels showed very good accuracy.

Conclusions: Ultrasound-imaging is an accurate technique for performing cervical zygapophysial joint nerve blocks in volunteers, except for the medial branch blocks of C7.

What We Already Know about This Topic

- Cervical zygapophysial (facet) joints can be a source of chronic pain for patients.
- Pain physicians use radiofrequency medial branch ablation of the nerve innervating the joint to decrease pain in these patients.

What This Article Tells Us That Is New

- In normal volunteers, ultrasound imaging was used to place needles near medial branches of the second through seventh cervical nerves innervating the facet joints and then tested with contrast spread using fluoroscopy. Placement was successful except for the seventh cervical nerve.

THE cervical zygapophysial joints are well-documented sources of chronic neck pain and headache, the prevalence among patients with chronic neck pain being 36–50%.[1,2] The zygapophysial joints from C3–4 to C6–7 are innervated by the medial branches of the spinal nerves' dorsal rami, each joint being supplied by the nerve above and below the corresponding segment. The nerves run across the center of the articular pillar of the vertebral body, where injection of local anesthetic can be used to selectively block nociceptive

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input from a single joint for diagnostic purpose. The same procedure is performed for the zygapophysial joint C2–3, which is innervated by the third occipital nerve.

To date, block of these nerves is the only scientifically validated method for diagnosing zygapophysial joint pain.[3] The standard technique involves fluoroscopic control. Ultrasound may offer the advantage of visualizing the target nerves,[4] which is obviously impossible with fluoroscopy. In a previous trial with 10 volunteers, the third occipital nerve was visible with ultrasound and could be anesthetized reliably in most cases.[5] This finding opened the perspective of using ultrasound as an alternative to fluoroscopy. However, there is a lack of studies that determine the accuracy of ultrasound-guided blocks of the nerves that supply the zygapophysial joints. These studies are essential for establishing the potential clinical usefulness of ultrasound guidance for this type of block.

The aim of this study was to test the accuracy of ultrasound-guided cervical zygapophysial joint nerve blocks in 60 healthy volunteers, as assessed by subsequent blinded evaluation of fluoroscopic image.

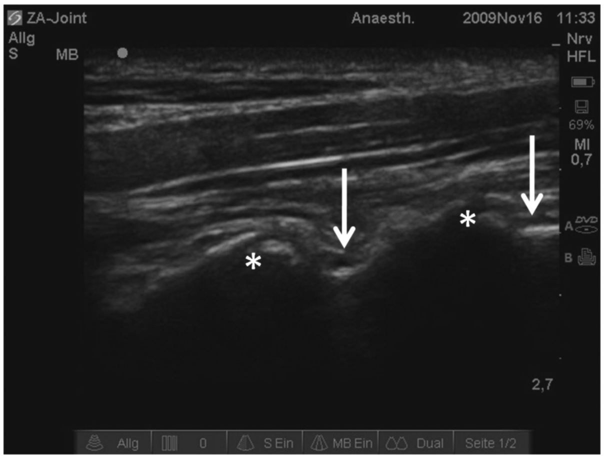

Fig. 1. Sonoanatomy of the cervical zygapophysial joint region cut in a longitudinal cranio-caudal plane. *Facet joint cleft. Bony target (*arrowhead*) for medial branch block (*i.e.*, the "groove" between two facet joints).

Materials and Methods

Healthy Volunteers

After approval of the study by the ethics committee of the University of Bern, Bern, Switzerland, written informed consent was obtained from 60 healthy volunteers. Volunteers were recruited *via* advertisement published on the campus of the University Hospital Bern and received 100 Swiss francs for their participation. Exclusion criteria were age younger than 18 yr, a history of alcohol abuse or intake of psychotropic drugs, intake of nonsteroidal antiinflammatory drugs during the week preceding the study, known coagulation abnormalities, a history of coronary artery disease, known allergy to local anesthetics or contrast dye, pregnancy, bacterial infection (systemic or in the cervical region), and fever of unknown origin.

Test under Investigation: Ultrasound-guided Needle Placement

Each volunteer was positioned in the lateral position on a fluoroscopy table with the side to be tested upward. A Sequoia 512® Ultrasound System (15L8w; Acuson Corporation, Mountain View, CA) with a 14-MHz high-resolution linear transducer with a maximal axial resolution of 0.28 mm and a maximal horizontal resolution of 0.42 mm was used.

All of the interventions were performed by the same physician (A.S.), who is experienced in musculoskeletal and nerve ultrasound and familiar with the ultrasound anatomy of the cervical zygapophysial joint region. He was trained in the blocks described in this article by the principal investigator (U.E.) of the study that first described the ultrasound-guided block of the third occipital nerve.[5] A.S. has performed these kinds of blocks on a regular basis since 2006.

Each of the zygapophysial joints C2–3 to C6–7 were located by ultrasound, according to the publication of Eichenberger *et al.*[5] First, the lateral aspect of the neck was scanned in a transverse plane in the region of the mastoid process, and by moving the transducer caudally, the most superficial situated bony landmark of the upper cervical spine (*i.e.*, the transverse process of C1) was visualized. A few millimeters caudal to this structure, the vertebral artery usually could be located by color Doppler and followed until it entered the transverse foramen of C2, where the C2–C3 zygapophysial joint could be located posteriorly. Here the transducer was turned approximately 90 degrees until the typical longitudinal view of the cervical zygapophysial joint region appeared (fig. 1), and each level could be determined by simply counting the "hills" (joints) and "grooves" (articular pillars) downward.

After an overview of the anatomy had been gained, the skin was disinfected and the ultrasound transducer was packed in a sterile plastic cover. Three different ultrasound-guided needle placements were performed in each volunteer: either at level third occipital nerve/C4/C6 or at the level C3/C5/C7. Determination of the level of needle placement and the side (left or right) was based on a computer-generated randomization list. We used 22-gauge needles with 75-mm length (Spinocan Quinke; Braun Medical AG, Sempach, Switzerland). The needles were placed under ultrasound guidance toward the center of the articular pillar at the bottom of its groove (for the medial branch blocks C3–C6), the junction of the articular pillar and transverse process (for the medial branch block C7), or the joint cleft of the facet joint C2–3 (in the case of the third occipital nerve) using an "out of plane" approach advancing the needle from anterior to posterior. After needle placement, 0.2 ml contrast dye (iopamidol 300 mg/ml) was injected.

Needle position and contrast dye spread were documented immediately with a lateral and anterior-posterior flu-

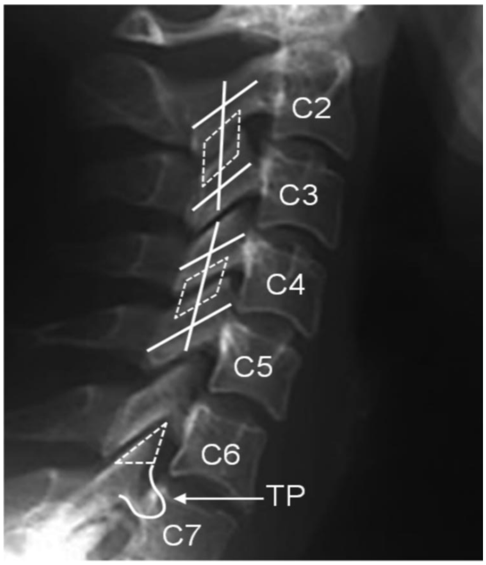

Fig. 2. Definition of the different target areas: (1) Third occipital nerve block: Needle tips located within the dashed parallelogram at the level C2–3 were classified as correctly placed. (2) Medial branch blocks C3–C6: Needle tips located within the dashed parallelogram (example shown here: level C4–5) were classified as correctly placed. (3) Medial branch block C7: Needle tips located within the dashed triangle were classified as correctly placed. TP = transverse process C7.

oroscopic picture (Ziehm Vision; Ziehm Imaging GmbH, Nürnberg, Germany), which were saved for later assessment by a blinded experienced pain practitioner (M.C.).

Definition of a Correct Target Point

The blinded pain practitioner evaluating the fluoroscopic pictures used the following criteria to define a needle tip position as "correctly placed" (as depicted in fig. 2):

1. Third occipital nerve: Needle tips located within the dashed parallelogram (level C2–3) were classified as correctly placed. The length of each of the four sides of the parallelogram is equivalent to one half the distance between the perfect target point (*i.e.*, the center of the joint cleft C2–3) and the center of the articular pillars above and below and the anterior and posterior margin of the articular pillars, respectively.
2. Medial branch C3–C6: Needle tips located in the dashed parallelogram were classed as correctly placed (example: level C4–5). The length of each of the four sides of the parallelogram is equivalent to one half the distance between the perfect needle tip position (*i.e.*, the center of the articular pillar) and the joint clefts above and below and the anterior or posterior margin of the articular pillars, respectively.
3. Medial branch C7: Needle tips located in the dashed triangle were classified as correctly placed. This triangle is delineated caudally by the transverse process of C7, posteriorly by the articular cleft C6/7, and anteriorly by the image of the vertebral body of C7.

The distribution pattern and spread of the injected contrast dye were determined for descriptive purposes and classified as (1) distribution within the target site (according to the definition of the "correctly placed" needle tip positions), (2) numbers of levels covered by contrast, (3) paraforaminal spread (spread of contrast dye around the intervertebral foramen on the lateral view), or (4) other pattern of spread.

Randomization, Blinding, and "Purposeful" Misplacement of Certain Needles

To allow blinding of the person assessing the fluoroscopic pictures and to calculate the appropriate agreement statistics, some of the ultrasound-guided needle placements were purposefully misplaced.

A "misplaced" needle position was placed at the following anatomic region: Joint cleft of the zygapophysial joint C3–4 for the medial branch C3, joint cleft of the zygapophysial joint C4–5 for the medial branch C4, joint cleft of the zygapophysial joint C4–5 for the medial branch C5, joint cleft of the zygapophysial joint C5–6 for the medial branch C6, joint cleft of the zygapophysial joint C5–6 for the medial branch C7, correct position of a C3 medial branch block for the third occipital nerve.

The blinded assessor was left unaware about the concept of purposeful misplacements until all assessments were done. Of the three needle placements for each of the 60 volunteers, one or two were purposefully misplaced based on computer-generated random numbers. The overall number of misplaced needles was known only by the study statistician (S.T.) and kept confidential until all radiographs were read.

Statistical Analysis

Sample size was determined using the width of the confidence interval around the κ statistic[6]: assuming a proportion of 59% correctly placed ultrasound-guided needles (determined by the randomization) and a κ value of 0.85, 60 volunteers with 180 interventions would be required to have a width of the 95% CI of 0.16. Clustering of interventions within volunteers was not taken into account for this sample size calculation.

The following three parameters were calculated to estimate the accuracy of the ultrasound-guided nerve blocks, separately for needle placement (primary analysis) and contrast dye distribution (secondary analysis).

1. Raw agreement is the proportion of placements in which both raters (*i.e.*, the physician who placed the needles using ultrasound and the blinded assessor using the radiographs) agreed that the needle or contrast dye was or was not correctly placed. This measure can be misleading, especially in situations in which the two raters believe that the prevalence of the correct placement will be high (*i.e.*, the agreement could be high simply by chance).
2. Chance-corrected agreement using the κ statistic[7]: Cohen's κ avoids spuriously high agreement because it dis-

counts the proportion of agreement that is expected by chance alone. κ has a maximum of 1 (indicating perfect agreement) and a minimum of −1 (indicating worse than chance agreement, which would be highly unlikely in this context). A value of 0 indicates no agreement better than chance. Values above 0.6 usually are considered as indication of "good" agreement and values higher than 0.8 as "very good" agreement. Although κ avoids the problem of spuriously high raw agreement, it provides inadequately low values in situations in which the proportion of positive ratings is extremely high,[8] as was the case in this study (see Results).

3. Chance-independent agreement using the Φ statistic[9]: Φ is based on the odds ratio derived from a 2 × 2 table representing the ratings of the needle-placing physician and the blinded assessor of the radiographs. It is independent of the level of chance agreement and thus overcomes one of the main disadvantages of κ. Φ also ranges from 1, indicating perfect agreement, to −1, indicating perfect disagreement, and it can be interpreted in the same way as κ.

To allow for clustering of interventions within participants, bias-corrected 95% bootstrap CIs were calculated based on 2,000 replications. Bootstrap samples were drawn at the participant level. Differences in accuracies across levels were analyzed by a formal test of interaction with the use of the Q statistic robust for clustering of assessments within participants. All statistical analyses were done using Stata 11.2 (StataCorp. 2009, Stata Statistical Software Release 11; StataCorp, College Station, TX,).

Results

One hundred eighty needles were placed in the 60 volunteers. Of these 180 attempts, 107 targeted the correct location and 73 were purposefully misplaced. The median age of the 60 volunteers (31 women) was 25 yr (interquartile range, 23–32 yr) and the median body mass index was 22 kg/m^2 (interquartile range, 21–24 kg/m^2).

Needle Placement

The correct needle location, as assessed by radiography, was reached in a total of 82 of 107 (77%) attempts at correct placement. A "purposefully misplaced" location was reached in 73 of 73 (100%) attempts (*i.e.*, the blinded assessor classified all "purposefully misplaced" needles as truly misplaced). The overall raw agreement was very good (*i.e.*, 87%, 95% CI 81–91%; fig. 3). The chance-corrected agreement statistic indicated good agreement with a κ of 0.74 (95% CI 0.64–0.83) and chance-independent agreement was very good with a Φ of 0.99 (0.99–0.99). The accuracy of needle placement varied statistically significantly between levels (fig. 4): the accuracy of needle placement was significantly worse at the medial branch of C7, whereas all other levels showed very good accuracy.

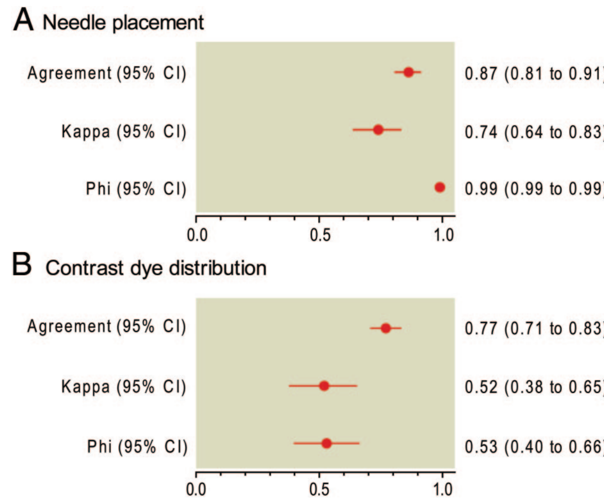

Fig. 3. Agreement statistics to quantify the accuracy of ultrasound-guided needle placement (*A*) and contrast dye distribution (*B*) (point estimates [*blobs*] and 95% CI [*whiskers*]).

Contrast Dye Distribution

In 90 of the 107 attempts of targeting the correct location, the contrast dye reached the bony target, corresponding to a simulated block success rate of 84%. Contrast dye of 49 of the 73 purposefully misplaced needles was classified as missing the target by the blinded assessor. This means that in 24 of the 73 attempts at purposeful misplacement, the contrast dye still reached the bony target of an otherwise correctly performed nerve block.

The incidence of foraminal spread of contrast dye was 3%. Two segments were covered by contrast dye in 23 of the 180 (12%) attempts, most commonly the region between the third occipital nerve and the medial branch of C3, which were covered at the same time in 14 attempts.

Overall raw agreement was 77% (95% CI 71–84%; fig. 3). The chance-corrected agreement statistic indicated mod-

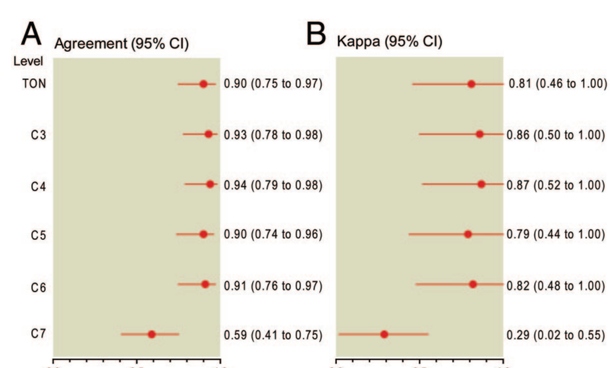

Fig. 4. Agreement statistics for needle placement stratified by level (point estimates [*blobs*] and 95% CI [*whiskers*]). The accuracy of needle placement varied significantly between the different levels both for agreement (*A*) (*P* value for interaction <0.001) and for κ (*B*) (*P* value for interaction = 0.034): it was significantly worse at the medial branch of C7, whereas all other levels showed very good accuracy. TON = third occipital nerve.

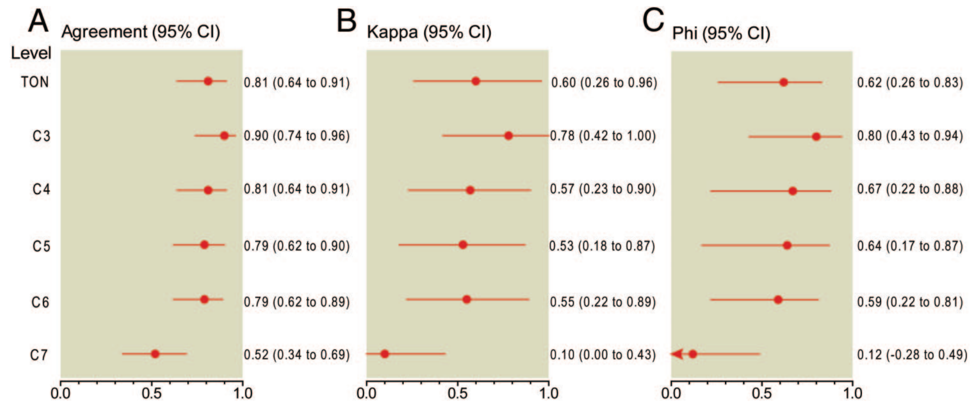

Fig. 5. Agreement statistics (*A*, raw agreement; *B*, kappa; *C*, phi) for contrast dye distribution stratified by level (point estimates [*blobs*] and 95% CI [*whiskers*]). Accuracy of contrast dye distribution varied between the different levels: it was significantly worse at the medial branch of C7, whereas all other levels showed very good accuracy. Formal statistical significance for differences among levels was reached only for the raw agreement statistic (P value for interaction $<$0.001, whereas P value for interaction = 0.124 for κ statistics and P = 0.127 for ϕ). TON = third occipital nerve.

erate agreement with a κ of 0.52 (95% CI 0.39–0.64) and moderate chance-independent agreement with an Φ of 0.53 (0.40–0.66). However, the accuracy of contrast dye distribution varied between levels: the accuracy of contrast dye distribution was significantly worse at the medial branch of C7, whereas all other levels showed very good accuracy. Formal statistical significance for differences among levels was reached only for the raw agreement statistic but not the other parameters (fig. 5).

Adverse Events

All the 60 volunteers completed the study. No problems, such as severe procedural pain or paresthesia, occurred during the procedure that necessitated premature termination. No serious adverse events were observed. Two volunteers reported postprocedural neck pain that lasted for a total of 1 week and resolved spontaneously.

Discussion

In this study, which was performed in a population of healthy volunteers, we found ultrasound-guided nerve blocks of the zygapophysial joints to have good to excellent accuracy, with the exception of the block of the medial branch C7.

For the levels C2–3 (third occipital nerve) to C6, the success rate for a simulated block, as assessed by contrast dye spread, was very high, ranging from 94% for the block of the medial branch of C4 to 88% for the block at C6 and third occipital nerve. The great exception was the block of the medial branch of C7, for which the success rate was only 41%.

One reason for the lower success rate of this block can be the difficulty in scanning the distal cervical vertebra because the presence of the clavicle renders the placement of the transducer problematic. An additional problem is that the target is located slightly deeper under the skin than are the other targets, which decreases the visibility.

The incidence of aberrant spread of contrast dye observed in this study (injected volume 0.2 ml) was 3% for foraminal spread and 12% for spread over more than one segment, although aberrant spread of contrast dye might have been detected more frequently if computed tomography would have been applied instead of fluoroscopy. Multilevel spread was observed in most cases for the block of the third occipital nerve, with spread to the medial branch of C3. This is because of the close proximity of the two targets and is consistent with a recent study investigating the incidence of aberrant spread of fluoroscopic-guided cervical medial branch blocks after application of 0.25 ml contrast dye volume per nerve.[10]

This is, to our knowledge, the first study describing the accuracy of ultrasound-guided cervical zygapophysial joint nerve blocks. We are also not aware of any other study with a design that implied randomly allocated placement and displacement, as well as blinded assessment, thereby allowing the calculation of formal agreement statistics. In general, although the literature on ultrasound-guided blocks has greatly expanded in recent years, most studies focused on description of the techniques. The feasibility of techniques does not necessarily imply meaningful use in clinical practice. The current study is in line with the urgent need for validating ultrasound-guided blocks to provide an evidence-based background for their clinical use.

There are several advantages of ultrasound imaging for performing cervical zygapophysial joint nerve blocks compared with the conventional fluoroscopic technique. Ultrasound guidance avoids radiation exposure and can be performed outside lead shielded facilities. Although radiation exposure of a single fluoroscopic-guided nerve block may be low, usually several blocks on different occasions are required to identify the symptomatic joint or to rule out zygapophysial joint-mediated pain, which may lead to considerable radiation exposure of patients and staff.[11] An additional advantage is that the actual target (*i.e.*, the zygapophysial joint supplying nerve, may be identified in most people using ultrasound imaging,[4] which obviously is not the case with fluoroscopy. Although our study was performed primarily in young and nonobese volunteers, our results indicate that ultrasound-guided blocks are accurate when the bony landmark of the fluoroscopic image is considered as the gold standard. In addition, the possibility to visualize the nerves by ultrasound can account for the variability of the nerve location in relation to the bony target.[4,12] This characteristic is expected to further improve the target specificity of the injections.

Some limitations need to be mentioned. The study was performed in a population of healthy volunteers with little or no degenerative changes. Therefore, the extent to which the results are applicable to patients with cervical zygapophysial joint-related pain and advanced spondylosis is unknown. In addition, the median body mass index was 22 kg/m^2, which is rather low. The success rate could be less in obese patients. It cannot be overemphasized that the ultrasound anatomy of the cervical zygapophysial joint region is demanding. Even when performed by experienced practitioners, visualization of the structures is not always possible. The results of the findings presented here are not applicable to settings in which less-experienced practitioners perform the blocks. These limitations need to be critically taken into account; we do not recommend the performance of these kinds of ultrasound-guided blocks in patients until additional clinical studies have demonstrated sufficient precision and safety of this novel technique in patients with chronic neck pain.

In cases of positive diagnostic block, radiofrequency neurotomy can be performed to treat the pain.[13–15] Fluoroscopy remains the standard imaging technique for this procedure. Because of lack of safety data, ultrasound guidance cannot be recommended at this time for denervation procedures in cervical zygapophysial joint-mediated pain.

We conclude that ultrasound imaging may be a highly accurate technique for the performance of nerve blocks of the cervical zygapophysial joints, with exception of the C7 medial branch blocks. The results encourage studies on patients to investigate the applicability of this technique to clinical practice.

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