

Medical screening of recreational divers for cardiovascular disease: Consensus discussion at the Divers Alert Network Fatality Workshop

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ABSTRACT

Cardiac events are responsible for a significant proportion of recreational diving fatalities. It seems inescapable that our current systems for selecting suitable recreational diver candidates and for longitudinal monitoring of diver health are failing to exclude some divers at high risk of cardiac events. Based on review of practice in parallel sporting disciplines and of the relevant literature, a series of recommendations for screening questions, identification of disqualifying conditions and risk factors, and investigation of candidates with risk factors was drafted. Recommendations for ongoing health monitoring in established divers were also generated. These recommendations were promulgated and debated among experts at a dedicated session of the Divers Alert Network Fatality Workshop. As a result, we propose a modified list of screening questions for cardiovascular disease that can be incorporated into health questionnaires administered prior to diver training. This list is confluent with the American Heart Association (AHA) preparticipation screen for athletes. The exercise stress test unmask inducible cardiac ischemia and quantifies exercise capacity, and remains the tool of choice for evaluating diver candidates or divers with risk factors for coronary disease. An exercise capacity that allows for sustained exercise at a 6-MET intensity (possibly representing a peak capacity of 11-12 METS) is an appropriate goal for recreational divers.

INTRODUCTION

In 2008, Denoble *et al.* published a paper entitled “Scuba injury death rate among insured DAN members” [1]. Using data gathered over a seven-year period they showed that the annual death rate (due to dive accidents) among insured DAN members averaged 16.4 per 100,000 persons. An obvious question is how should this figure be viewed? One interpretation might be that the death rate is relatively low and comparable to that for other active sports that are not considered dangerous. For example, about 13 joggers per 100,000 participants die each year from heart attacks [2]. Another interpretation might be that every death is a tragedy and that all practicable steps should be taken to reduce fatalities to as near to zero as possible. In fact, both views have merit. Diving can rightfully be lauded as a relatively safe “adventure sport,” but nevertheless, if important contributing factors to fatal accidents could be identified, then targeted prevention programs might be instituted.

In the latter regard, a second recent study by the DAN group has presented an opportunity. Denoble *et al.* [3] divided the causative process in 947 fatalities into four

sequential components: trigger; disabling agent; disabling injury; cause of death. Although drowning was the pre-eminent cause of death, the sequential component approach to the analysis identified the more important precursor events. Of note, cardiac incidents constituted 26% of disabling injuries. Associations with cardiac incidents included a history of cardiovascular disease and age greater than 40. One implication of these data is that the current systems for medical screening of diver candidates and for health surveillance in established divers are failing to exclude or adequately manage individuals at risk of cardiac events.

All recreational diver training agencies require that a prospective diver undergo some form of medical screening prior to undertaking a diving course. There are two prevalent approaches. In the most widely used system the diver candidate completes a screening questionnaire issued by the training agency. In the absence of any positive responses, the diver may proceed to training. If there are any positive responses the candidate is compelled to see a physician for a “physical examination.” One of the most commonly used screening question-

naires was developed by the Undersea and Hyperbaric Medical Society Diving Committee on behalf of the Recreational Scuba Training Council (RSTC) [4]. The second and less commonly used system is for all recreational diver candidates to undergo a "diving physical" with a physician irrespective of the answers elicited by a screening questionnaire. Typically the physician will utilize a pro-forma medical questionnaire (such as the RSTC form) to elicit relevant history, and a physical examination will be conducted. The physician will then make a judgment about whether it is appropriate for the candidate to proceed to diver training. There has been debate over which of these approaches is most appropriate, with limited data supporting both the screening questionnaire approach [5,6] and an approach requiring all candidates to undergo a medical consultation [7].

There is no system in place for longitudinal health surveillance of recreational divers. Completion of a screening questionnaire or a medical evaluation by a physician may be required if a diver undertakes continuing diving education courses, but in the absence of such courses it would be possible for someone who learned to dive at 20 years of age to still be diving at 50 years having never undergone any form of intervening health evaluation. This contrasts sharply with the customary requirement for occupational divers to undergo a comprehensive medical evaluation annually; a contrast that is all the more stark when it is considered that occupational divers are arguably a younger, more homogeneous and healthier group.

The discussion session documented here was convened to review the present systems for recreational diver selection and surveillance with specific reference to detection and exclusion of relevant cardiovascular disease. The session followed papers on the implications of various cardiovascular conditions in diving [8], the epidemiology of cardiovascular disease [9] and relevant screening methods [10], all of which are published in the present series. For the purposes of setting the agenda we took the position that the screening questionnaire approach described above is the most widely used system, and that discussion around optimizing evaluation of diver candidates for cardiovascular disease should start there. Thus, the agenda was built around key steps in selection and longitudinal monitoring of recreational divers beginning with the use of screening questionnaires prior to diver training.

These steps are depicted in Figure 1 (*facing page*). The process begins with a diving candidate completing the screening questionnaire. The first point for discus-

sion is whether the current iteration of the RSTC form contains the most appropriate questions for screening cardiovascular disease. If there are no positive responses to the questions the candidate may proceed to diver training. Positive answers to the pre-diving cardiac screening questions will reveal either existing cardiovascular diagnoses/symptoms that would contraindicate diving, or milder disease/risk factors that require further consideration. The second point for discussion is the defining of those cardiac diagnoses or associated symptoms that would mandate an automatic decision to disallow diving pending treatment (if possible) and further review. The third point for discussion is the definition of risk factors in an otherwise asymptomatic candidate that would prompt investigation prior to a decision about suitability for diving. The fourth point for discussion is the advice given to physicians with respect to investigating these risk factors. The final point for discussion is recommendations for longitudinal health review in existing divers with particular reference to cardiovascular disease.

WORKSHOP DISCUSSION

Cardiovascular components of screening questionnaire

To provide a starting point for discussion, the authors identified those questions on the current RSTC screening form that were relevant to cardiovascular disease and compared them to those appearing on the AHA preparticipation screening questionnaire for competitive athletes [11]. Items appearing in the latter and missing from the former are listed in Table 1 (*Page 292*). We put it to the discussants that these items should be considered for inclusion on the RSTC form.

There was no disagreement with the implied concept that some important diagnoses might be missing from the questionnaire in its current form. However, there was much discussion around the potential confusion that a more comprehensive list could introduce. Some industry representatives pointed out that diver candidates were encouraged to "tick yes if unsure," and since many would never have heard of some of the diagnoses, they would therefore be "unsure" and be compelled to tick "yes." It therefore was generally agreed that if the items from the AHA list were added to the RSTC questionnaire then the terminology would need maximal simplification, and the criteria for ticking yes would need to be very explicit (such as, "Do you carry the diagnosis of any of ..."; or "have you ever been diagnosed with..."). Interpretation of questions phrased in this way would not require understanding of the listed diagnoses.

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FIGURE 1 – Schema for evaluation of cardiovascular conditions and risk factors in divers

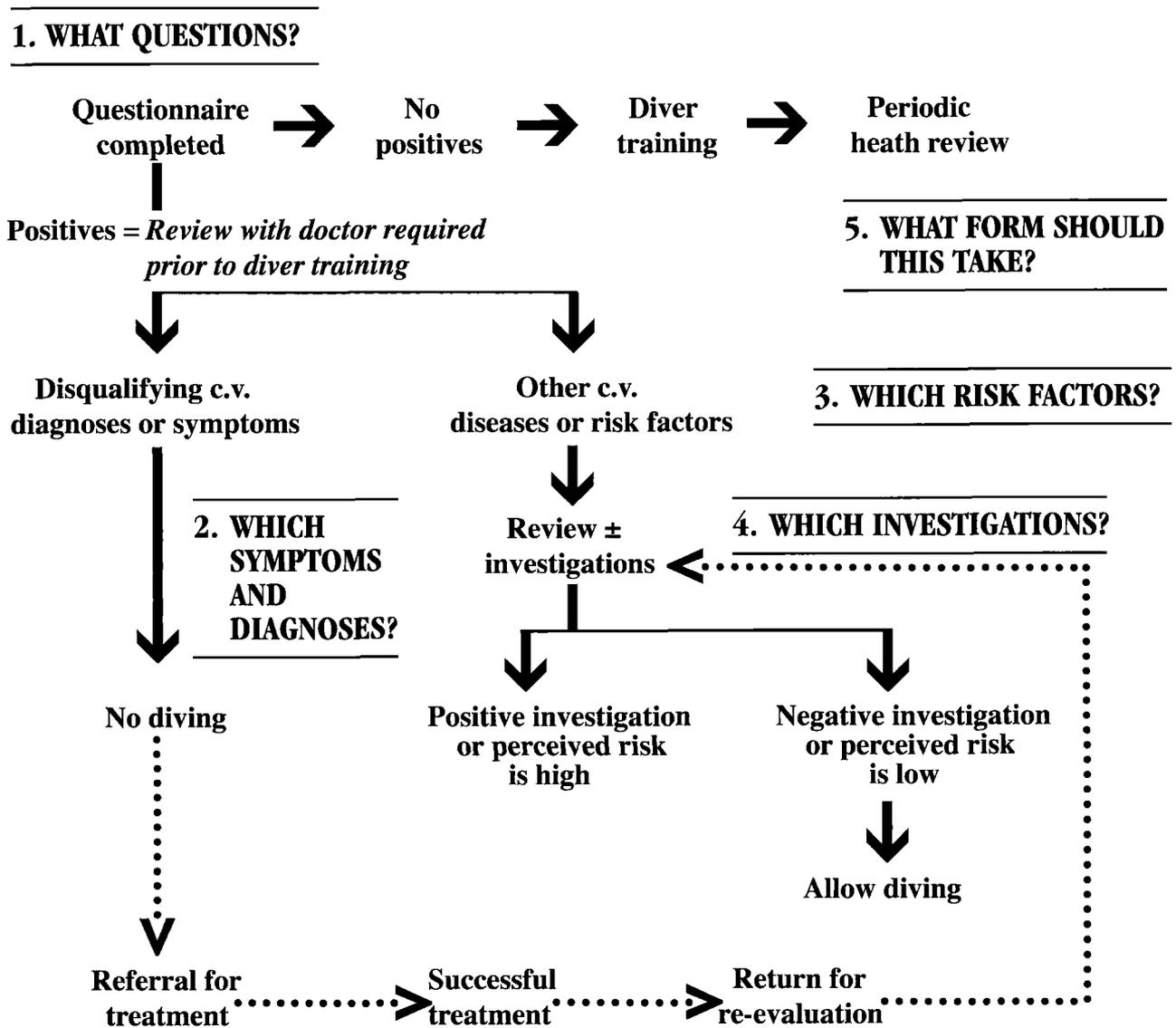


FIGURE 1 – Schema for evaluation of cardiovascular conditions and risk factors in a recreational diving candidate. This formed an agenda for the discussion session and discussion took place on each of the numbered points in boxes (see text for elaboration). *c.v.* = *cardiovascular*

TABLE 1 – AHA questions omitted from RSTC form

Exertional chest pain / discomfort (appears on RSTC form as “angina”)
Excessive exertional and unexplained shortness of breath / fatigue associated with exercise
Prior recognition of a heart murmur
Premature death < 50 years due to heart disease in 1 relative
Disability from heart disease in a close relative < 50 years of age
Do you or a close relative suffer from hypertrophic or dilated cardiomyopathy, long QT syndrome, or other ion channelopathies, Marfan syndrome, or clinically important arrhythmia ?

TABLE 1 – Items appearing on the AHA pre-participation screening questionnaire for competitive athletes that do not appear on the current RSTC pre-diving screening questionnaire.

Some of the individual items on the list were debated. In particular there was concern that benign heart murmurs were prevalent, and that this item would force many candidates into unnecessary medical review. It was agreed that a qualifying statement would be required which excluded murmurs that had been investigated and designated benign. Finally, several commentators expressed the view that some treated cardiovascular conditions (such as hypertension and hypercholesterolemia) probably do not significantly increase risk in diving, and should not trigger the requirement for a medical examination. This view was opposed by expert cardiologists present, who pointed out that the adequacy and appropriateness of treatment (of hypertension, for example) could not be evaluated by the questionnaire, and that treated or not, these problems still constituted risk factors for more serious cardiovascular disorders. Based on this discussion, a proposal for a modified list of questions for the recreational diving screening questionnaire is presented in Table 2 (*facing page*).

Cardiovascular problems that would prohibit diving

The next question considered was which cardiovascular diagnoses or manifestations of cardiac disease would prompt the reviewing physician to make an automatic recommendation not to dive. As a starting point for discussion, the authors proposed a list based on existing elements of the RSTC questionnaire and on items to be added from the AHA athletic sports preparticipation screening questionnaire. This list included:

- untreated symptomatic coronary disease (history of angina or heart attack);
- cardiomyopathy;
- long QT syndrome;

- arrhythmias causing impairment of exercise tolerance or consciousness; and a history of poor functional capacity of cardiac origin.

For completeness, we added severe valvular lesions, complex congenital heart disease (including cyanotic heart disease and unrepaired atrial septal defect), and the presence of an implantable defibrillator, none of which were directly specified in either questionnaire.

There was some discussion about whether a patent foramen ovale (PFO) should appear on this list. However, there was strong consensus among the experts present that a PFO is not a contraindication to diving. If a diving candidate reported a PFO on their screening questionnaire this would indicate discussion of the implications with a diving physician, but it would not mandate intervention prior to diving. Unfortunately, further discussion in this phase of the workshop was dominated by ongoing debate on the complexity of the terminology associated with some of the added questions. Although this helped develop the wording of questions appearing in Table 2, it did little to inform selection of disqualifying cardiac conditions. It is notable, however, that no particular objections were voiced to the items appearing in Table 3 (*facing page*).

Several qualifying comments are necessary in relation to this list. First, as implied in Figure 1, not all of them represent an absolute dead end in the path to recreational diving. For example, a candidate with coronary artery disease who undergoes an intervention might proceed to diving, providing he/she can subsequently demonstrate good functional capacity (see later) without induction of myocardial ischemia. Second, the significance of valvular lesions is highly dependent on the nature of the lesion (stenotic vs. regurgitant) and its severity.

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TABLE 2 – Proposed revised screening questions

1. Are you over 45 years of age and can answer yes to one or more of the following:
 - _ currently smoke a pipe, cigars, or cigarettes;
 - _ you are currently receiving medical care;
 - _ you have a family history (in blood relatives) of heart attack or stroke;
 - _ you have been diagnosed with either of:
 - _ a high cholesterol level or
 - _ diabetes mellitus
 even if controlled by diet alone?

2. Have you ever been told you have high blood pressure (or do you take medicine for high blood pressure)?

3. Have you ever had a “heart attack”, heart surgery, or blood vessel surgery?

4. Do you experience chest pain / discomfort or excessive / unexplained shortness of breath or fatigue associated with exercise?

5. Do you struggle to perform moderate exercise (example: walk 1 mile in 12 minutes)?

6. To your current knowledge, has a close “blood” relative less than 50 years old suffered disability or premature death due to heart disease?

7. Have you ever been told you have heart valve disease? Tick no if you have a heart murmur that has been described as “insignificant” or “benign.”

8. Have you or (to your current knowledge) a close “blood” relative ever been told that you/they suffer from:
 - _ a cardiomyopathy;
 - _ long QT syndrome;
 - _ Marfan’s syndrome; or
 - _ a heart rhythm problem that limits exercise, causes fainting or needs a pacemaker?

9. Are you presently taking prescription medicines?

TABLE 2 – Revised screening questions for cardiovascular disease based on workshop discussion. If the answer to any of these questions was positive, a review with a doctor, preferably trained in diving medicine, would be required prior to undertaking diver training.

TABLE 3 – Proposed automatic initial contraindications

Untreated symptomatic coronary artery disease
Dilated or obstructive cardiomyopathy
Long QT syndrome (or other channelopathies if reported)
Arrhythmias causing impairment of exercise tolerance or consciousness
Poor functional capacity of presumed cardiac origin
Severe cardiac valvular lesions (and lower grade stenotic lesions)
Complex congenital cardiac disease, including cyanotic heart disease and unrepaired atrial septal defect
Presence of an implantable cardiac defibrillator

TABLE 3 – Cardiovascular diagnoses or symptoms that would result in an automatic initial recommendation not to dive.

Virtually all severe lesions would contraindicate diving, but many patients with milder regurgitant lesions could dive if their functional capacity was adequate. Stenotic lesions are of greater significance and probably contraindicate diving if more than mild. Finally, it is acknowledged that there may be rare cases in which a diagnostic label does not accurately reflect risk in diving (such as a mild "cardiomyopathy"), and in such cases, careful evaluation and investigation by an expert might result in diving being allowed.

Cardiovascular risk factors that would prompt investigation

It was generally accepted that any non-disqualifying cardiovascular diagnosis revealed on the questionnaire (that is, diagnoses not listed in Table 3, such as hypertension) would be evaluated "on their own merits" by the reviewing doctor. It was not the aim of this discussion to derive an approach to this. Rather, the intent of this phase of the discussion was to review the spectrum of non-symptomatic risk factors for cardiac disease that would trigger further investigation either before a diving candidate progressed to diver training or for an established diver presenting for health review. The question put was:

"In the asymptomatic patient with no CV diagnoses, what risk factors for coronary artery or other heart disease identified from the questionnaire should prompt further investigation for inducible cardiac ischemia or other pathology prior to diving?"

The discussants were particularly invited to consider the risk factors that would be identified by positive answers to questions 1, 4, 5, 6, 7 and the family history component of question 8 in Table 2.

There was essentially no debate about the content of the risk factor list. However, there was ongoing discussion about the significance of "prior recognition of a heart murmur," which further informed the wording of question 7 in Table 2. There was consensus among the discussants involved that the wording shown in Table 2 should minimize the possibility of unnecessary investigation of benign murmurs. There was also discussion about how to designate a relative of "hereditary importance," and it was resolved to use the term "blood relative," which should be widely understood.

Investigation of diver candidates with risk factors for cardiac disease.

The primary focus of this discussion was on the most appropriate investigation for significant occult coronary artery disease in divers with relevant risk factors as

previously defined. The authors proposed a draft statement for discussion which read:

"Where the risk of ischemic heart disease is intermediate or greater the reviewing physician should assess functional capacity to exclude ischemia and to assure the candidate has an adequate exercise capacity to sustain continuous activity at 6 metabolic equivalents (MET; multiples of assumed resting metabolic rate)."

This statement drew heavily on the discussion following the cardiac session on previous day of the workshop in which the widely cited recommendation for a peak exercise capacity of 13 METs in recreational divers was debated. There was a reasonable consensus among involved discussants that a 13-MET peak capacity might be an unrealistic "standard" for application "across the board," and it therefore carried the risk of being ignored. In support of this notion, Dr. Neal Pollock cited a weighted mean peak capacity of 11.9 MET in the 14 published studies on divers that included true aerobic capacity assessment [12], Aerobic capacity data from his own laboratory revealed a mean peak capacity of 12.6 ± 2.7 (7.1-20.3) METs in 103 males and 11.4 ± 2.4 (7.1-17.3) MET in 29 females [13].

It was generally agreed that the metabolic requirement for normal swimming in modest to benign diving conditions was around 4 METs, and a safety margin is gained by having the capacity to sustain a 6-MET exercise intensity.

Discussion around this proposal highlighted the dual purpose of the stress test and the associated logic for choosing it over alternative investigations for coronary disease risk described earlier in the meeting [10]. Specifically, the stress test is a widely used and well-understood investigation for inducible ischemia, and in addition, it measures the subject's exercise capacity, which is an important aspect of assessing suitability for diving. The recommendation of a desirable standard for exercise capacity will inevitably be somewhat arbitrary, but there was no disagreement with "continuous activity at 6 METs."

There was no discussion on the specific issue of how this would best be assessed. One obvious option would be to tailor an exercise test specifically to this purpose and require the subject to exercise at 6 METs for 20-30 minutes. Another approach recognizes that the sustainable exercise capacity is usually about 50% of peak capacity. This would translate to a peak exercise capacity on stress testing of about 12 METs, which doubles as a desirable target for exclusion of inducible myocardial ischemia. [8] For the reasons cited above there was little

enthusiasm among discussants for designating a 12-MET peak capacity as a required or recommended standard. Nevertheless, if a diver were capable of achieving 12 METs in a stress test without symptoms or relevant electrocardiographic changes, this would be very reassuring in respect of both their risk of significant coronary disease and their exercise capacity. Although the subject of debate in respect of phraseology, it was generally agreed that a higher sustainable capacity could be seen as an “ideal” goal for divers such as divemasters and instructors who participate in activities where a high standard of readiness could be expected, and for divers who habitually entered challenging environments.

There was some discussion around how the reviewing physician would define “intermediate” risk in selecting candidates for stress testing, and this was resolved with reference to the Framingham Risk Score [14] as a widely available and easily applied means of risk assessment. Thus, divers found to be at intermediate risk (10-20% 10-year cardiovascular event rate) or high risk (above 20% 10-year event rate) should have further evaluation of their risk for a cardiovascular event while diving. This section of the session ended with discussion of the need for periodic re-evaluation after such investigation. There was no disagreement with the proposal that this is necessary. It was agreed that the nature and periodicity of follow-up should be at the discretion of the reviewing physician.

Longitudinal health surveillance of recreational divers

The authors identified two potential opportunities for continuing health surveillance in recreational diving: at enrollment for continuing education courses; and prior to embarkation on dive charter vessels. The completion of health screening questionnaires often occurs in these situations (particularly continuing education) already. We also identified the need to encourage voluntary re-evaluation, and identified a number of goals in this regard. Specifically, these were:

- to educate divers on the need to present for review of suitability for diving after any sustained change in health;
- to educate divers not to dive and to present for medical review when unwell;
- to educate divers to have regular health checks with family physician; and
- to educate divers to present for review of their cardiovascular status at age 45 for males or 55 for females.

There was no debate over most of these recommendations. However, there was considerable discussion over the use of medical screening questionnaires prior to embarkation on charter vessels. Some commentators were adamant that this did not occur and would introduce too many difficulties for dive operators trying to interpret the answers. Others were equally adamant that many charter boats included medical questions in their waiver documentation, and this is known to be true in Queensland, Australia. There was no consensus on the desirability of this practice, but it did become clear that there is no standardized questionnaire for use in this context. It was acknowledged that comprehensive screening questionnaires such as the RSTC form were not suitable for dive charter use, and that a shorter and highly discriminatory tool needs to be developed for that situation.

CONCLUSIONS

This workshop has brought clarity to some issues relevant to screening recreational diver candidates for diver training. The RSTC health screening questionnaire for candidate selection is less comprehensive in relation to cardiovascular conditions and risk factors for cardiac disease than the athletics preparticipation screening questionnaire designed by the AHA. A redrafted list of questions is proposed (*Table 2*) which rectifies potential discrepancies in the RSTC form [4], but with careful attention to minimizing ambiguity and unnecessary medical review of candidates.

The exercise stress test remains the intervention of choice for investigating diver candidates with risk factors for ischemic heart disease because it provides additional information about their functional capacity. Recreational diver candidates should be capable of a sustained 6-MET workload, and this could reasonably be deduced from a 12-MET peak exercise capacity on stress testing.

Longitudinal health monitoring of recreational divers is a universally supported goal, and the principles of selection and investigation in relation to cardiac disorders outlined in Figure 1 and discussed earlier in this paper would apply perfectly well to divers undergoing health review.

Re-evaluation of health prior to continuing education courses is broadly acceptable and currently practiced. There is less consistency and more controversy around the use of health screening questionnaires prior to dive charter trips. There is a need for a standardized short, highly discriminatory questionnaire that dive charter operators could choose to administer if desired. ■

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