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Major Article

# Prevalence of *Staphylococcus aureus* and methicillin-resistant *S aureus* on environmental surfaces in Ohio nursing homes

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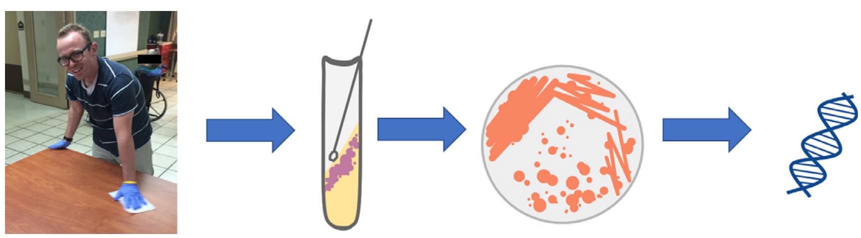

*Key Words:*
Contamination
Molecular typing
Antibiotic resistance
MRSA

***Background:*** Methicillin-resistant *Staphylococcus aureus* (MRSA) is common in medical institutions. We sought to examine the prevalence of *S aureus* on environmental surfaces in nursing homes and to obtain molecular information on contaminating strains.
***Methods:*** A total of 259 environmental samples were collected from 7 different nursing homes in Northeast Ohio (NEO), from suburban, urban, and rural settings. The presence of the *mecA* and PVL genes was determined, and *spa* typing was performed in order to identify molecular types.
***Results:*** The prevalence of *S aureus* was 28.6% (74/259). The prevalence of MRSA and methicillin-susceptible *S aureus* was 20.1% (52/259) and 8.5% (22/259), respectively. *S aureus* contamination in suburban, urban, and rural sites was 25.7% (38/148), 45.9% (34/74), and 5.4% (2/37), respectively. MRSA was detected in 16.9% (25/148) of suburban samples and 36.5% (27/74) of urban samples. No MRSA was found in rural samples. Nursing homes from urban areas had a significantly higher ($P < .001$) prevalence of *S aureus* compared to nursing homes from suburban and rural sites. Areas with high nurse touch rates were the most commonly contaminated.
***Conclusions:*** We found differences in the prevalence of *S aureus* and MRSA in nursing homes in different regions of NEO. Part of these differences may result from transfers from hospitals; the urban nursing homes had 4 to 15 hospitals nearby, whereas suburban and rural locations had 1 to 3 hospitals within the area.


## BACKGROUND

*Staphylococcus aureus* is a common pathogen that can cause a wide range of symptomatic infections. Approximately one-third of the population is colonized with *S aureus*, primarily in the nose and throat.[1] In some patients, *S aureus* can cause severe infections and bacteremia leading to significant mortality. Since the 1950s, methicillin-resistant *S aureus* (MRSA) has primarily been a nosocomial infection in many institutions such as hospitals, community centers, and nursing homes. MRSA can spread directly between individuals or indirectly via fomites.[2] Hospital-associated MRSA is often acquired within the hospital setting and is one of many infections exhibiting increased antimicrobial resistance.[3]

As the population continues to age and health care costs rise, an increasing number of individuals are exposed to nursing home (NH) settings. Prior studies have demonstrated that MRSA carriage by residents in nursing homes can reach or exceed 50% of residents,[4,5] which may be higher than colonization levels in hospital facilities.[6] Because of the difficulty of dealing with MRSA colonization and infections, some facilities even refuse to accept incoming patients with MRSA.[7]

Time spent in NHs can pose a significant risk for the acquisition of nosocomial infections due to transportation of residents to and from clinical appointments and the bidirectional flow of individuals from hospitals to NHs and back, as well as the frequency of new patients admitted on a weekly basis and the transfer of patients between rooms within the facility. Because older individuals are at a greater

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risk of infection due to immunosenescence, chronic illness, exposure to antimicrobial agents, the presence of pressure ulcers, and use of indwelling devices, NHs provide an ideal environment for the acquisition and spread of MRSA and other antibiotic-resistant infections,[8] including methicillin-susceptible strains of *S aureus* (MSSA). Whereas patients and medical staff are important sources for MRSA spread, contamination of the environment by nosocomial pathogens may also contribute to within-facility transmission.[9,10] Effective infection control measures must therefore include consideration of MRSA contamination in the environment.[11]

The purpose of this study was to examine the prevalence of both *S aureus* and MRSA on environmental surfaces within NHs and to determine pathogen characteristics including molecular type and antibiotic resistance phenotype.

## MATERIALS AND METHODS

### *Participating nursing homes and locations*

A convenience sample of 7 NHs was selected based on access to facilities, and these NHs were then grouped according to geographical settings in Northeast Ohio (NEO): urban or non-urban. Each nursing home contained between 75 and 120 beds. NH size was similar within each geographical area. One NH was rural, 2 NHs were urban, and 4 NHs were suburban; 5 NHs were owned by one company. Consent to acquire environmental samples within each facility was obtained from each NH, and a confidentiality letter was given to a representative for each site.

### *Environmental samples*

Each environmental sampling location was chosen based on input from staff, including nurses, *state-tested nursing assistants*, doctors, nursing home administration, and transport personnel, to determine the sites that are most frequently touched in this setting. Standards of practice were also taken into consideration, such as nurses passing meds, schedules for various activities, and locations where nursing home staff work, upon reviewing policies and procedures. Thirty-seven environmental sampling surfaces were chosen based on this analysis and were standardized across all NHs.

### *Sample collection and processing*

Samples were collected using sterilized Swiffer pads (Procter & Gamble; Cincinnati, OH), as previously described.[12] As closely as possible, an approximately 3-inch × 3-inch site was sampled; samples were taken at approximately the same time of day at each facility. After the sample was collected, the Swiffer pad was placed into a Whirl-Pak bag (Nasco; Fort Atkinson, WI), which was then sealed and placed into a biohazard bag. Sterile gloves were changed between each sample. This process was repeated until all 37 samples were obtained within each location. Samples were then sealed in a biohazard bag and securely placed in a cooler to be transported to the lab for processing within 24 hours of collection. Samples were cultured and bacteria identified as previously described.[13]

### *Molecular analysis*

All environmental *S aureus* isolates were subjected to molecular characterization. Panton-Valentine leukocidin (PVL) genes were amplified to confirm *S aureus* isolates by polymerase chain reaction using primers and methods previously described.[14] The methicillin-resistance (*mecA*) gene was also amplified to further classify isolates as MRSA or MSSA.[15] Determination of *spa* type was performed using published methods and primers.[16,17] Based-Upon Repeat Pattern analysis to identify *spa* clonal complexes (*spa*CC) was conducted using the Ridom StaphType software version 2.2.1 (Ridom GmbH; Wurzburg, Germany) using default parameters as previously described.[18]

### *Antimicrobial susceptibility testing*

*S aureus* isolates were tested for susceptibility to benzylpenicillin, oxacillin, tetracycline, erythromycin, ciprofloxacin, moxifloxacin, minocycline, clindamycin, trimethoprim-sulfamethoxazole, quinupristin/dalfopristin, gentamicin, levofloxacin, linezolide, daptomycin, vancomycin, rifampin, minocycline, tigecycline, and nitrofurantoin by the VITEK 2 system (bioMérieux; Durham, NC) using AST-GP71 cards according to the manufacturer's instructions, in accordance with the Clinical Laboratory Standards Institute standards and previously described methods.[19]

### *Statistical analysis*

Frequency distributions and proportions were calculated for the categorical variables. Chi- square tests were used to assess relationships among variables. Logistic regression was used to observe the significant differences of *S aureus* positivity among study sites. Statistical significance was assessed at the $\alpha = 0.05$ level. All statistical analyses were conducted using SAS 9.3 (SAS Institute, Inc.; Cary, NC).

## RESULTS

### *Prevalence of S aureus in the environment*

A total of 259 environmental swabs were collected from 7 nursing homes located in NEO. The overall prevalence of *S aureus* in environmental samples was 28.6% (74/259; 95% confidence interval [CI], 23.0-34.0), with the prevalence of MRSA and MSSA being 20.1% (52/259; 95% CI 15.0-24.0) and 8.5% (22/259; 95% CI 5.1-11.9), respectively. The overall prevalence of *S aureus* in suburban, urban, and rural sites was 25.7% (38/148; 95% CI, 18.6-32.8), 45.9% (34/74; 95% CI, 34.6-57.3), and 5.4% (2/37; 95% CI, 0-12.7), respectively. Similarly, the overall prevalence of MRSA in suburban and urban sites was 16.9% (25/148; 95% CI, 0.1-0.2) and 36.5% (27/74; 95% CI, 0.2-0.5), respectively. No MRSA was found in rural sites. Nursing homes in urban areas had a significantly higher ($P < .001$) prevalence of *S aureus* (45.9%) compared to those in non-urban (rural and suburban) locations (21.6%) (Table 1). Table 2 shows the distribution of environmental *S aureus* in the nursing homes across all sampling sites. Sites 2 through 7 are compared with site 1 (reference site). The prevalence of *S aureus* was significantly different in sites 4, 6, and 7 ($P = .004$, $P = .001$, and $P = .014$, respectively) (Table 2).

The most common places that were contaminated were areas that nurses touched, a finding that was observed at 57.1% (4/7) of total NHs. These places included chart folders, keyboards at the nurses stations, and nursing cart countertops (Table 3). Another common area for contamination, at 42.9% (3/7) of total NHs, was wheelchair arm

**Table 1**
Association of *Staphylococcus aureus* positive samples with nursing homes located in urban and non-urban sites of Northeast Ohio

| | *S aureus* (N = 259) | | | |
|---|---|---|---|---|
| Sites | Yes (n = 74) n (%) | No (n = 185) n (%) | Total | *P* value |
| Urban | 34 (45.9) | 40 (54.1) | 74 | |
| Non-urban | 40 (21.6) | 145 (78.4) | 185 | <.001* |

*Significant *P* value.

**Table 2**
Distribution of *Staphylococcus aureus* in Northeast Ohio nursing homes

| | *S aureus* (N = 259) | | |
|---|---|---|---|
| Site | Positive (n = 74) n (%) | Negative (n =185) n (%) | *P* value |
| 1[†] | 10 (27.0) | 27 (73.0) | REF |
| 2[†] | 10 (27.0) | 27 (73.0) | .828 |
| 3[†] | 11 (29.7) | 26 (70.3) | .543 |
| 4[‡] | 2 (5.4) | 35 (94.6) | .004* |
| 5[†] | 7 (18.9) | 30 (81.1) | .324 |
| 6[§] | 18 (48.6) | 19 (51.3) | .001* |
| 7[§] | 16 (43.2) | 21 (56.8) | .014* |

*Significant *P* value.
[†]Suburban site.
[‡]Rural site.
[§]Urban site.

**Table 3**
Most frequently contaminated areas sampled

| Sample ID | Prevalence of *Staphylococcus aureus* in nursing homes (%) | Most commonly touched by | Nursing home region |
|---|---|---|---|
| WAR | 42.9 | Nursing staff | Suburban, urban |
| WR | 57.1 | Resident | Suburban, urban |
| CF | 57.1 | Nursing staff | Suburban, urban |
| KB-NS | 57.1 | Nursing staff | Suburban, urban, rural |
| CT-NC | 57.1 | Nursing staff | Suburban, urban |
| HEE | 42.9 | Physical therapist, resident | Suburban, urban |
| DT | 42.9 | Resident | Suburban, urban |
| OD-1 | 42.9 | Administrative staff | Suburban, urban |
| OD-2 | 42.9 | Administrative staff | Suburban, urban, rural |
| TB-C-1 | 42.9 | Nursing aide, resident | Suburban, urban |
| TB-C-2 | 42.9 | Nursing aide, resident | Suburban, urban |
| CT-NS | 42.9 | Nursing staff | Suburban, urban |

*CF*, chart folder; *CT-NC*, countertop of nursing cart; *CT-NS*, countertop 1 of nurses station; *HEE*, handle of exercise equipment in physical therapy room; *KB-NS*, keyboard at nurses station; *OD-1*, office desk 1 in staff office; *OD-2*, office desk 2 in staff office; *TB-C-1*, table 1 in cafeteria; *TB-C-2*, table 2 in cafeteria; *WAR*, wheel and arm rest; *WR*, walking rail in physical therapy room.

rests of facility-owned wheelchairs used to transport residents, as well as walking rails in physical therapy rooms, office desks in staff offices, table tops in cafeterias, dresser tops in resident rooms, and hand exercise equipment in physical therapy rooms (Table 3).

*Molecular characterization*

Molecular characterization of all isolates was conducted by amplification of the PVL and *mecA* genes and *spa* typing. The prevalence of the *mecA* gene among *S aureus* isolates was 70.3% (52/74). Among the *mecA*-positive isolates, 33.8% (25/74), 36.5% (27/74), and 0% (0/74) were distributed among suburban, urban, and rural NHs, respectively. Eighteen different *spa* types were identified from 74 positive isolates, with t002 (Fig 1 and Table 4) being the most common at 35.1% (26/74), with 61.5% being found in suburban NHs (16/26) and 38.5% (10/26) in urban NHs, followed by t008 with 100% (10/10) being found only in urban NHs. Another common type was t334, which showed up in all NHs and was the *spa* type of 12.1% (9/74) *S aureus*. t334 was primarily found in urban NHs (77.8%, 7/9). Despite multiple attempts, 5 isolates were untypeable. Twenty-nine PVL-positive isolates were identified (29/74, 39.2%), with 44.8% (13/29) and 55.2% (16/29) being distributed among suburban and urban NHs, respectively. No PVL-positive isolates were found among environmental isolates from rural nursing homes.

*Antibiotic susceptibility of environmental isolates*

All *S aureus* isolates were tested for antibiotic susceptibility. All isolates were resistant to benzylpenicillin, 70.3% (52/74) were resistant to oxacillin, 8.1% (6/74) were resistant to gentamicin, 64.9% (48/74) were resistant to levofloxacin, 4.1% (3/74) were resistant to moxifloxacin, 64.9% (48/74) were resistant to erythromycin, 45.9% (34/74) were resistant to clindamycin, 1.4% (1/74) were resistant to quinupristin/dalfopristin, 2.7% (2/74) were resistant to minocycline, 20.3% (15/74) were resistant to tetracycline, 1.4% (1/74) were resistant to rifampicin, and 82.4% (61/74) were multidrug resistant (Fig 2). Urban and suburban locations had the highest percentages of multidrug-resistant isolates, with 41.9% (31/74) and 37.8% (28/74), respectively. Among MRSA isolates (n = 52), 11.5% (6/52) were resistant to gentamicin, 82.3% (43/52) to ciprofloxacin, 59.6% (31/52) to levofloxacin, 3.8% (2/52) to moxifloxacin, 75.0% (39/52) to erythromycin, 48.1% (25/52) to clindamycin, 1.9% (1/52) to quinupristin-dalfopristin, 1.9% (1/52) to minocycline, 21.2% (11/52) to tetracycline, and 1.9% (1/52) to rifampcin.

## DISCUSSION

Residents of nursing homes are commonly colonized with MRSA, but there is a limited understanding of the dynamics and determinants of spread in this setting,[20-22] as relatively little research has been done in nursing home environments compared to the hospital setting.[23-26] Furthermore, a number of variables including antibiotic use and prior hospitalization have been identified as contributing factors to MRSA prevalence in long-term care facilities.[4,27,28] This study further examined the prevalence and molecular epidemiology of environmental samples collected from 7 nursing homes.

When looking at the data among nursing homes in each region, the prevalence of MRSA was highest among urban nursing homes at 36.5% (27/74; 95% CI, 0.2-0.5). Urban NHs in our study had an average of 4 to 15 hospitals within an 8-mile radius, whereas rural NHs had an average of 1 to 3 hospitals. The rates of discharges, re-admits, room transfers, and transportation to and from hospitals were

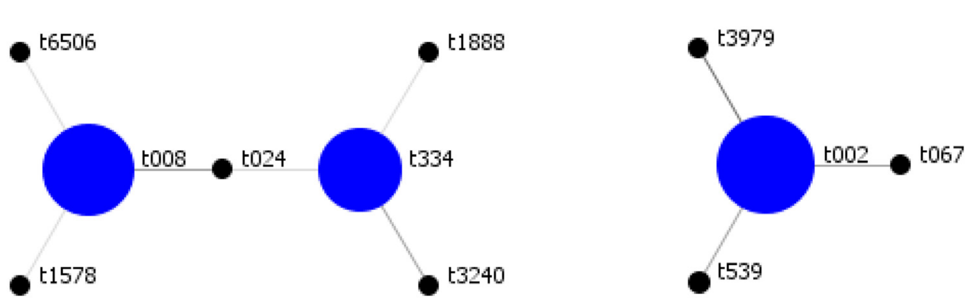


**Fig 1.** Based-Upon Repeat Pattern analysis of *spa* types from environmental samples in Northeast Ohio nursing homes. Figure denotes *spa* types found across all locations sampled. t008 is a common community-associated lineage; t002 is a common hospital-associated lineage.

**Table 4**
*spa* types identified in nursing home environmental samples

| Item | Isolates (n) | Typeable isolates (%)* | Site numbers (types) |
|---|---|---|---|
| t002 | 26 | 37.7 | 1, 2, 3, 5, 6, 7 (suburban, urban) |
| t008 | 10 | 14.5 | 2, 3, 6, 7 (suburban, urban) |
| t334 | 9 | 13.0 | 1, 3, 5 (suburban, urban) |
| t024 | 1 | 1.4 | 4 (rural) |
| t045 | 6 | 8.7 | 1, 6, 7 (suburban, urban) |
| t065 | 1 | 1.4 | 3 (suburban, urban) |
| t067 | 1 | 1.4 | 1 (suburban) |
| t091 | 2 | 2.9 | 3, 7 (suburban, urban) |
| t1149 | 1 | 1.4 | 7 (urban) |
| t1578 | 1 | 1.4 | 6 (urban) |
| t1888 | 1 | 1.4 | 2 (suburban) |
| t209 | 4 | 5.8 | 1, 6 (suburban, urban) |
| t216 | 1 | 1.4 | 3 (suburban) |
| t3240 | 1 | 1.4 | 4 (rural) |
| t3979 | 1 | 1.4 | 6 (urban) |
| t539 | 2 | 2.9 | 7 (urban) |
| t6506 | 1 | 1.4 | 6 (urban) |

*After 2 attempts of *spa* typing among the 74 isolates, 5 were not typeable.

highest in urban NHs, and rural NHs tended to have more residents staying for long-term care; however, this should be interpreted with caution due to the inclusion of only a single rural NH in the current study. According to Mor et al,[29] 40% of Medicare recipients are discharged to a post-acute setting, half of this number to a skilled nursing facility. This study also states that one-fifth of these beneficiaries are re-hospitalized.[29] These results indicate that the intensity of patient movement between NHs and hospitals could increase MRSA prevalence in the nursing home environment, but additional quantitation is needed. We were unable to examine the prevalence and molecular types of MSSA and MRSA in the hospitals that served these nursing homes, a limitation of our study.

Molecular analysis indicated that the overall *mecA* prevalence in our positive environmental samples was 70.3% (52/74), with suburban and urban prevalence being 33.8% (25/74) and 36.5% (27/74), respectively; however, these results may not be generalizable to other facilities or areas. Our study used a convenience sample of nursing homes and may not be applicable to other facilities. Examining these data and further investigation into antibiotic use in short-term stay patients (ie, patients frequenting hospitals and entering nursing homes for rehab) prior to entering a NH and after would enhance our understanding of antibiotic use as a contributing factor for increased prevalence of MRSA among urban and non-urban NHs in NEO. Increased antibiotic stewardship programs in both NHs and hospitals could greatly reduce the prevalence of MRSA; however, further study would have to be conducted to understand and model relationships between antibiotic use and the environmental contamination burden.

*spa* typing was conducted on all environmental isolates. t008, the most common MRSA clone in the community as well as in hospitals in the United States,[30] was common in urban NHs. t008 is a common cause of skin and soft tissue infections. Transfer from infected or colonized individuals into the environment shows the importance of hand hygiene and proper disinfection within the NH. Another common hospital-associated MRSA type, t002, was found to have a 35.1% (36/74) and 61.5% (16/26) prevalence, respectively, in suburban and urban NHs. Implementing MRSA surveillance programs upon admission to NHs both from the community and from transfers from hospitals could reduce the introduction of these strains into the facilities.

The study team was able to review the infection control policies, including environmental cleaning recommendations, in 5 of 7 of our examined NHs. The policies speak extensively about protecting against person-to-person contact, isolation of patients, and hand hygiene; however, the policies also include language suggesting that MRSA cannot live in the environment. A previous study shows that MRSA can in fact live in the environment for up to 7 months.[2,31] As such, a clear intervention that could be implemented in these facilities is an update of training policies for workers. The policy also mentions reducing the transport of patients from room to room for patients who have skin lesions that could potentially contaminate the environment. The only mention of environmental cleaning was the use of a germicide or hospital germicide weekly or as needed. No data existed on how often environmental surfaces were cleaned, nor was there a log of the type of germicide used or date of last cleaning for areas sampled.

The determinants that may have played a role in the areas that were most contaminated are hand hygiene among health care workers, frequency of personnel use of these areas, level of contamination among surfaces, and the amount of time spent and interaction with patients by health care workers working in these areas. A study in

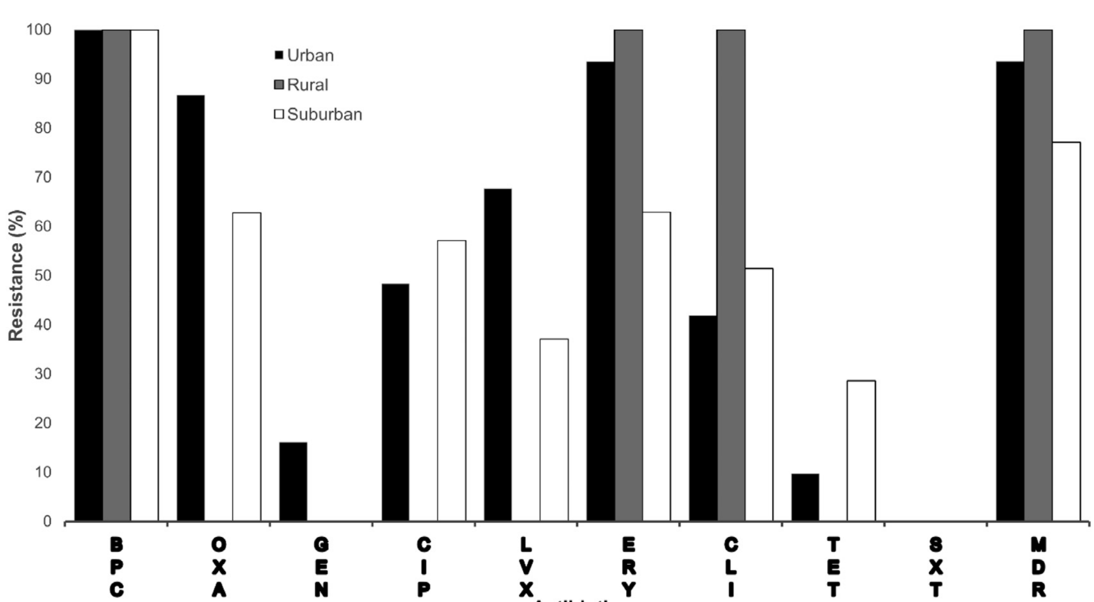


**Fig 2.** Antibiotic resistance profiles of environmental *Staphylococcus aureus* isolates among suburban, urban, and rural nursing homes in Northeast Ohio.

California tested objects in 10 nursing homes that were highly touched and found that 16% of objects touched were MRSA positive, including areas that were frequently touched by nursing and medical staff .[10] As environmental contamination increases, the prevalence of health care worker hand contamination conceivably also may increase, creating a cycle of transmission that may be difficult to break.

## CONCLUSIONS

NHs should take precautions when cleaning environmental surfaces and recognize that these surfaces may play a role in morbidity and mortality among patients in health care facilities. They should also consider infection control implementation when it comes to *S aureus* and MRSA transmission in areas where medical staff reside. NHs should take greater measures to ensure that nursing staff as well as other health care workers are using proper hand hygiene, as staff members could potentially be the greatest risk factor for the spread of *S aureus* and MRSA between the environment and patients. Cleaning products used, frequency of cleaning, placement of residents, and hand hygiene among health care workers are areas of interest to be investigated further in the future. Exploration into demographics, multilocus sequence typing profiles, and hospital surveillance upon discharge to suburban and urban NHs should also be considered.

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