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Aetiology of in-hospital cardiac arrest on general wards☆

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ABSTRACT

Aim: Aetiology of in-hospital cardiac arrests (IHCAs) on general wards has not been studied. We aimed to determine the underlying causes for IHCAs by the means of autopsy records and clinical judgement of the treating consultants. Furthermore, we investigated whether aetiology and preceding vital dysfunctions are associated with long-term survival.

Design and setting: Prospective observational study between 2009–2011 including 279 adult IHCA patients attended by medical emergency team in a Finnish university hospital's general wards.

Results: The median age of the patients was 72 (64, 80) years, 185 (66%) were male, 178 (64%) of events were monitored/witnessed, first rhythm was shockable in 42 (15%) cases and 53 (19%) patients survived six months. Aetiology was determined as cardiac in 141 events, 73 of which were due to acute myocardial infarction. There were 138 non-cardiac IHCAs; most common causes were pneumonia (39) and exsanguination (16). No statistical difference was observed in the incidence of objective vital dysfunctions preceding the event between the cardiac and non-cardiac groups (40% vs. 44%, $p = 0.448$). Subjective antecedents were more common in the cardiac cohort (47% vs. 32%, $p = 0.022$), chest pain being an example (11% vs. 0.7%, $p < 0.001$). Reviewing all 279 IHCAs, only shockable primary rhythm, monitored/witnessed event and low comorbidity score were independently associated with 180-day survival.

Conclusions: Cardiac aetiology underlies half of the IHCAs on general wards. Both objective and subjective antecedents are common. However, neither the cardiac aetiology nor the absence of preceding deterioration of vital signs were factors independently associated with a favourable outcome.

Introduction

Survival to discharge after in-hospital cardiac arrest (IHCA) remains poor (10–20%) and it has practically remained unchanged through the recent decades.[1–4] Cardiac arrest outside hospital is presumed to be of cardiac origin if no other definite signs exist; IHCAs on the other hand are often preceded by derangements in vital signs and cardiac aetiology is not assumed by default.[5,6] Furthermore, IHCA victims often have several comorbidities in addition to the concurrent illness, making the situation even more precarious.[7,8]

Data on the definite aetiology of IHCAs on hospital general wards are very limited although the epidemiological understanding could result in improved and more prompt peri- and postarrest care. Bergum et al. studied 258 IHCAs and found cardiac causes to be responsible for 60% of the IHCAs.[9] Wallmuller et al. reported similarly the percentage to be 63, and cardiac aetiology was associated with better outcome.[10] However, in these thorough studies only 50% and 19% of IHCAs occurred on general wards while the rest occurred in specialized departments inside hospital like emergency departments, intensive care units and post anaesthetic care units.[9,10]

The aim of this study was to shed light on the aetiology and antecedents to IHCAs occurring on hospital's general wards and investigate, whether the aetiology and antecedents are associated with outcome.

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Methods

Ethics

The Ethics Committee of the Tampere University Hospital (TAYS) approved the study protocol (Approval no: R08116; clinicaltrials.gov NCT00951704). National Institute for Health and Welfare and Regional State Administrative Agencies gave their consent to analyse forensic autopsy findings. Informed consent from the patient/relatives was waived as this study was purely observational.

Hospital

TAYS is one of the five university level tertiary referral centres in Finland with 71,000 somatic admissions per year. TAYS has a closed model, mixed surgical-medical intensive care unit (ICU) with 24 beds and approximately 2000 annual admissions. A separate cardiac ICU provides care for post operative cardiothoracic patients. Excluding the ICUs, paediatric wards, post anaesthetic care units and emergency department TAYS has 750 general ward beds, 6% of which have automated monitoring capabilities.

Definitions

IHCA was defined as cessation of cardiac activity, confirmed by the absence of signs of circulation, in a hospitalized patient who had a pulse at the time of admission.[11] Three outcomes were reported for IHCA patients in this study. ROSC (return of spontaneous circulation) was defined as return of a spontaneous perfusing rhythm with a palpable pulse.[11] Time-fixed outcomes, being alive 24 h and 180 days after the initial ROSC, were also reported. The main outcome was the 180-day survival. Vital dysfunctions preceding IHCAs were defined as hospital's positive objective MET activation criteria present during a given time period before the events, and are also referred as afferent limb failures (ALFs) in the MET literature.[12–15] Our hospital's objective MET criteria are presented in Table 3. Because the time period considered to be incorporated in ALF analysis is very disperse (starting from 15–60 min before the event and ending at 420–1440 min before the event),[12–15] we defined the time frame in this study to be 20–720 min. Definitions for subjective symptoms preceding IHCAs (antecedents) are also presented in Table 3. Included symptoms were based on out-of-hospital cardiac arrest studies.[16,17]

Medical emergency team

The medical emergency team (MET) was implemented in January 2009. It is led by an ICU physician accompanied by two ICU nurses. The MET operates 24/7, responding to both IHCAs and other medical emergencies. During the study period, MET activation rate was approximately 10 calls per 1000 hospital admissions including IHCAs and 8.4 per 1000 admissions if just medical emergencies were included.

Data collection and exclusion criteria

Data on IHCAs were routinely prospectively collected by the MET attending the resuscitation attempts during the study period of 2009–2011. Known data on comorbidities, preceding vital dysfunctions, subjective antecedents and survival were noted from patient records. Age-adjusted Charlson comorbidity index (CCI) was calculated for each patient; the total score presents the cumulative negative impact that patient's diseases and age have on favourable outcome.[18]

Table 1
Specific reason for in-hospital cardiac arrest.

Cardiac reason for IHCA *n* = 141	
Acute myocardial infarction	73
Myocardial ischaemia (no acute infarction)	26[a]
Cardiac tamponade	5
Congestive heart failure	16
Complication after invasive cardiac intervention	9
Other	
Dilated cardiomyopathy	2
Cardiac amyloidosis	2
Cor pulmonale (after chronic pulmonary embolism)	1
Atrial fibrillation	1
Perimyocarditis	1
Aortic stenosis	2
Aortic regurgitation	1
Mitral regurgitation	1
Ascending aortic dissection	1
Non-cardiac reason for IHCA *n* = 138	
Pulmonary embolism	12
Infection	
Pneumonia	39
Peritonitis	11
Urogenital infection	2
Erysipelas	1
Pancreatitis	3
Colechystitis	2
Sepsis NAS	6
Cirrhosis	3
Renal insufficiency	2
Exsanguination	
GI tract	10
Traumatic	3
Airway	1
Iatrogenic	2
Cerebral ischaemia	4
Anaphylaxis	2
Hyperkalemia	2
Hyponatremia	2
Hematologic malignancy	2
Malignant solid tumour	7
Mechanical airway obstruction	7
Vasovagal collapse	1
Acute mesenteric ischemia	1
Overdose of opioids/benzodiazepines	2
Hypoxia due to chronic lung disease	4
Reason unclear	7

Data are presented in numbers. IHCA, in-hospital cardiac arrest; NAS, not further specified; GI, gastrointestinal.
[a] In one case ischaemia was provoked by low hematocrit.

In case the resuscitation was successful or autopsy was not deemed necessary, aetiology of the cardiac arrest was classified according to the expert opinion of the consultant(s) responsible for the patient. The 'consultant's expert opinion' refers to the final conclusion of the aetiology (obtained from the patient records and/or the death certificate) after consultant(s) had assessed all relevant patient history and conducted all diagnostic tests and interventions deemed necessary; it does not refer to the first impression of the aetiology possibly recorded to the Utstein-style resuscitation form. Study personnel did not make assumptions about the aetiology.

No autopsies were conducted as part of this study protocol. Forensic autopsies must be conducted in certain situations according to the law and the cause of death investigation is led by the police. Medical autopsies are conducted if deemed necessary by the consultant responsible for the patient (e.g. the cause of death is considered uncertain). If either forensic or medical autopsy was conducted, the cause of the cardiac arrest was obtained from the autopsy records in case no ROSC was achieved or if ROSC was achieved but patient died during the following hours/day(s).

Paediatric IHCAs were not included in this study. IHCAs outside the general wards were excluded from further analyses.

Table 2
Patient characteristics, primary rhythm and outcome.

	IHCA due to cardiac aetiology ($N = 141$)	IHCA due to non-cardiac aetiology ($N = 138$)	p-value
Patient characteristics			
Age (median; Q_1, Q_3)	74 (64, 82)	70 (63, 77)	0.010
Sex (male)	94 (67)	91 (66)	0.898
Age-adjusted CCI (mean ± SD)	5.3 ± 2.4	4.8 ± 2.7	0.112
Arterial hypertension	88 (62)	78 (57)	0.316
Coronary artery disease	72 (51)	34 (25)	<0.001
Atrial fibrillation	44 (31)	35 (25)	0.279
Cardiomyopathy	4 (1.4)	0 (0.0)	0.122
Chronic heart failure	43 (31)	23 (17)	0.007
Aortic stenosis	13 (9.2)	4 (2.9)	0.043
Peripheral artery disease	22 (16)	15 (11)	0.244
Diabetes	44 (31)	36 (21)	0.345
Asthma	8 (5.7)	12 (8.7)	0.328
Chronic obstructive pulmonary disease	13 (9.2)	8 (5.8)	0.279
Renal insufficiency	23 (16)	13 (9.4)	0.086
Dementia	5 (3.5)	3 (2.2)	0.723
Malignancy	13 (9.2)	30 (22)	0.004
Previously healthy	4 (2.8)	4 (2.9)	1.000
Primary rhythm			
Asystole	45 (32)	47 (34)	
Pulseless electrical activity	51 (36)	78 (57)	
Ventricular tachycardia	9 (6.4)	2 (1.4)	<0.001
Ventricular fibrillation	30 (21)	1 (0.7)	
Unclear	6 (4.3)	10 (7.2)	
Monitored/witnessed arrest	91 (65)	87 (63)	0.795
Aetiology determination and outcome			
Autopsy conducted	81 (57)	72 (52)	0.376
Clinical judgement	60 (43)	66 (48)	
ROSC	72 (51)	68 (49)	0.765
Alive at 24 h	54 (38)	60 (43)	0.379
Alive at 180 days	29 (21)	24 (17)	0.499

Data are presented as numbers (percentages) if not otherwise indicated. IHCA, in-hospital cardiac arrest; CCI, Charlson comorbidity index; Malignancy, malignant solid tumor or hematologic malignancy; ROSC, return of spontaneous circulation.

Table 3
Comparison of antecedents to IHCAs related to cardiac vs. non-cardiac aetiology.

	IHCA due to cardiac aetiology ($N = 141$)	IHCA due to non-cardiac aetiology ($N = 138$)	p-value
Documented objective MET activation criteria (20–720 min before the IHCA)			
Respiratory rate (<5 or >24/min)	13 (9.2)	17 (12)	0.403
Peripheral arteriolar O_2 saturation (<90%)	29 (21)	30 (22)	0.811
Heart rate (<40 or >140/min)	12 (8.5)	18 (13)	0.222
Systolic blood pressure (<90 mmHg)	16 (11)	8 (5.8)	0.222
Any objective criteria	56 (40)	61 (44)	0.448
Multiple objective criteria	13 (9.2)	11 (8.0)	0.710
Recorded subjective antecedents (20–720 min before the IHCA)			
Respiratory distress	42 (30)	31 (23)	0.164
Chest pain	15 (11)	1 (0.7)	<0.001
Arrhythmias	2 (1.4)	1 (0.7)	0.574
Upper abdominal pain	3 (2.1)	4 (2.9)	0.681
Back pain	2 (1.4)	2 (1.4)	0.983
'Cold sweat'	5 (3.5)	5 (3.6)	0.972
Decrease in the level of consciousness	8 (5.7)	16 (12)	0.078
Any subjective antecedent	66 (47)	44 (32)	0.022
Multiple subjective antecedents	11 (7.8)	12 (8.7)	0.786

Data are presented as numbers (percentages). IHCA, in-hospital cardiac arrest; MET, medical emergency team.

Statistical analysis

Data are presented as numbers (percentages) if not otherwise indicated. The chi-square test, Student's t-test, Fisher's exact test and Mann–Whitney U test were used for comparisons between groups as appropriate. Multivariate logistic regression was applied with 'enter' model and the Hosmer–Lemeshow test was conducted to report the goodness-of-fit of the model. Tests were two-sided; $p < 0.05$ was considered significant and 95% confidence intervals were reported where appropriate. SPSS version 20 for Windows (SPSS Inc., Chicago, IL, USA) was used.

Results

Study population

Fig. 1 presents the excluded cases and the final cohort of 279 general ward patients attended by the MET because of an IHCA. Median age was 72 (64, 80) years, 185 (66%) were male and mean age-adjusted CCI was 5.0 ± 2.6. Primary rhythm was shockable (VT/VF) in 42 (15%) of the patients, ROSC was achieved in 140 (50%) cases and 114 (41%) patients survived the first 24 h. After six months, 53 (19%) patients were alive.

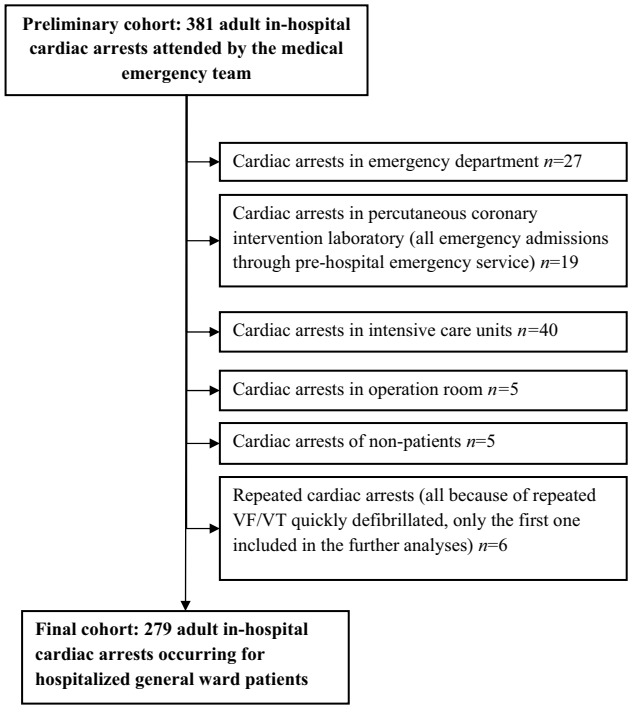

Fig. 1. Final cohort with the excluded cardiac arrests inside hospital during the study period. VF, ventricular fibrillation; VT, venticular tachycardia.

Aetiology

An autopsy was conducted in 153 (55%) patients, 84 of which were forensic autopsies and 69 medical autopsies. For the remaining 126 (45%) patients, the reason for IHCA was clinically assessed by the treating consultant(s); in 30 of these cases ROSC was not achieved and thus no further clinical or laboratory tests were conducted. Fig. 2 presents the determination of IHCA aetiology either as 'cardiac' or 'non-cardiac' and Table 1 lists the specific underlying aetiologies in both sub cohorts. Among patients with cardiac aetiology ($n = 141$, 51%), acute myocardial infarction was the most common cause for IHCA. Infections were the most prevalent sub group in 'non-cardiac' category. The method for aetiology determination (autopsy vs. clinical judgement) was not associated with the determined aetiology (aetiology was determined as 'cardiac' among 53% of the autopsied patients vs. 48% among the non-autopsied patients ($p = 0.376$)).

Cardiac vs. non-cardiac aetiology of IHCAs—characteristics and antecedents

Patients in the 'cardiac' and 'non-cardiac' cohorts had similar distribution of gender and cumulative comorbidity, but the 'cardiac' cohort was older (Table 2). Regarding the individual comorbidities, coronary artery disease, chronic heart failure and aortic stenosis were more prevalent in the 'cardiac' cohort. Solid or hematologic malignancies were more common among the 'non-cardiac' IHCA patients. Shockable rhythms were more common in the cardiac cohort, but non-shockable rhythms prevailed in both subcohorts. There were no differences in survival between the cohorts.

Altogether 117 (42%) IHCA patients had had positive objective MET activation criteria 20–720 min before the event, but there were differences between the 'cardiac' or 'non-cardiac' groups (Table 3). However, the overall incidence of subjective antecedents was higher in the 'cardiac' cohort, and from the individual antecedents 15 patients in the 'cardiac' cohort had had chest pain while only one had complained this symptom in the 'non-cardiac' cohort.

Table 4
Multivariate logistic regression analysis of factors independently associated with 180-day survival.

	Multivariate analysis		
	Odds ratio	95% CI	*p*-value
Shockable rhythm (VT/VF)	8.87	3.54–22.2	<0.001
Monitored/witnessed IHCA	2.46	1.13–5.36	0.024
Age-adjusted CCI	0.86	0.75–0.99	0.041
Any subjective antecedent	0.54	0.25–1.16	0.113
Cardiac aetiology	0.59	0.26–1.33	0.202
Any objective MET criteria	0.70	0.34–1.43	0.324
Sex (male)	0.81	0.40–1.65	0.563

CI, confidence interval; VT, ventricular fibrillation; VF, ventricular tachycardia; IHCA, in-hospital cardiac arrest; CCI, Charlson comorbidity index; MET, medical emergency team.

Shockable primary rhythm, monitored/witnessed IHCA and lower age-adjusted CCI were independently associated with 180-day survival, while cardiac aetiology and antecedent-free event were not (Table 4). The Hosmer–Lemeshow Chi-square test for multivariate logistic regression model was 4.44 ($p = 0.816$) indicating a good fit of the model.

Discussion

This study has two main findings. First, half of the IHCAs on hospital general wards were of cardiac origin and these IHCAs were more commonly preceded by subjective antecedents, especially chest pain, as compared to IHCAs of non-cardiac origin. Second, the multivariate logistic regression model demonstrated, that it is not the aetiology but low comorbidity, witnessed/monitored arrest and shockable primary rhythm that are independently associated with better long-term survival. To the best of our knowledge this is the first study to investigate the adjusted association between the aetiology of IHCA and outcome.

We investigated the aetiology of IHCAs on general wards, where continuous monitoring and staff resources are limited as compared to, for example, ICUs and emergency departments. Cardiac causes were still more common than non-cardiac causes, however approximately 10% less prevalent than reported in studies including all hospital departments.[9,10] Of the specific causes of IHCAs, acute myocardial infarction and myocardial ischaemia without later findings of infarction together accounted for 35% of the arrests. This finding is of utmost importance, considering that only 15% of all general ward IHCAs had a shockable primary rhythm. Congestive heart failure progressing to IHCA was the second largest individual reason for arrest within the cardiac aetiology group. Following pneumonia, exsanguination and pulmonary embolism were the second and third most common individual aetiologies for IHCAs in the 'non-cardiac group'. Aetiology of altogether 112 IHCAs could be directly classified according to the '4H4T'-rule,[6] even though excluding infections which potentially caused IHCAs due to hypovolaemia/hypoxia as well. This observation underlines the importance of including '4H4T'-rule in the advanced life support algorithm.[6]

Two thirds of the general ward IHCAs in our study were witnessed/observed. This occurrence has previously been associated with better outcome and was also confirmed in the present study.[19,20] In many IHCA studies the proportion of witnessed/observed cardiac arrests has been as high as 85–92% and it has been discussed, that previous IHCA studies represent poorly the actual patient population on general wards because of the high proportion of ICU/emergency department/cardiac care unit patients.[9,20,21] Brindley et al. excluded patients allocated to 'critical care units' and found that 58% of the IHCAs were witnessed/observed, which is in line with our findings.[19] Still, two

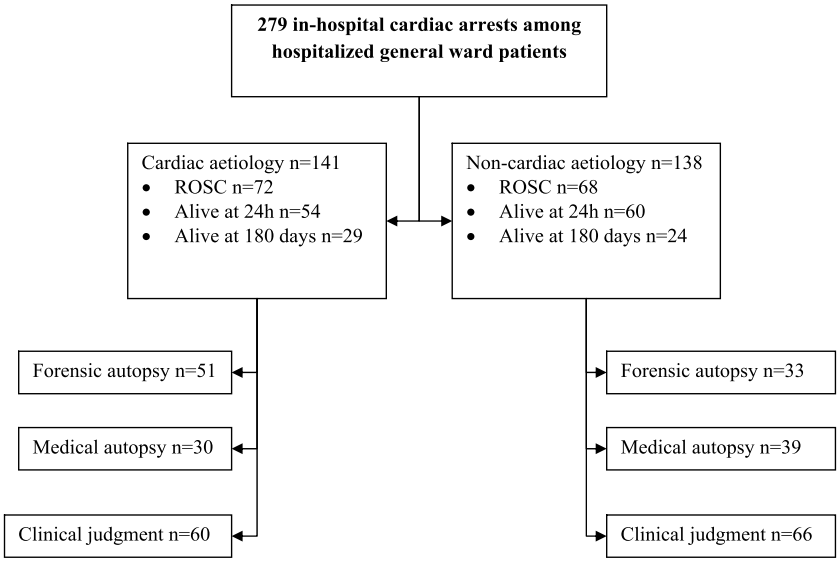

Fig. 2. Survival and methodology for determination of the aetiology among the study population. ROSC, return of spontaneous circulation.

thirds of patients experiencing a witnessed/observed cardiac arrest on general wards is rather high. However, today many hospitals have rapid response systems,[22] and although we did not record the exact number, there were several cases of IHCAs where the arrest occurred during MET review and thus the arrest was naturally 'monitored and observed'.

Both vital dysfunctions and subjective antecedents were common before IHCAs, despite our hospital had implemented MET at the time this study was initiated. Similar findings have been observed in Australia: implementing a rapid response system did not automatically eliminate the intervention delays in patient care.[23] It is pivotal to disengage these afferent limb failures.[12–15] Regardless of the fact that in our study these antecedents were not independently associated with worse outcome, some IHCAs could have been avoided either by appropriate interventions or ethically sound treatment limitations.

Low comorbidity, witnessed/monitored arrest and shockable primary rhythm were independently associated with six months' survival in a multivariate regression model. These pre- and peri-arrest factors have previously been reported to be associated with hospital- or short-term survival in univariate or multivariate analyses.[7,10,20,21,24] Our study also confirmed that these variables are associated with long-term survival, even when adjusted for gender and, for the first time, for preceding derangements and aetiology. One could have suspected that cardiac aetiology would have been associated with improved outcome, but this was not the case even with the other outcomes (ROSC, 24 h survival). Wallmuller et al. found cardiac aetiology to be associated with survival in a univariate analysis.[10] Naturally 'cardiac aetiology' depends on how the causes are classified, but in this study the classification was quite comparable to our study.[10] On the other hand, we studied the IHCAs on general wards, while Wallmuller et al. studied IHCAs mainly at the ICU of the emergency department. Our results show that if an IHCA occurs on general wards, immediate CPR (cardiopulmonary resuscitation) and shockable rhythm are the key factors for survival while comorbidities reduce probability of desired outcome.

This study has several limitations. First, as a single centre study our results may not apply in different health care settings or with distinct patient populations. Second, we could not include some factors known to be associated with at least short term survival in our multivariate analysis (e.g. adequate compression depth during CPR[25]). Third, in 11% of the cases no ROSC was achieved but autopsy was not deemed necessary; thus the consultant(s) aetiology determination relied only on patient history and pre- and periarrest factors. Fourth, the time frame of 20–720 min for preceding vital dysfunctions and subjective antecedents simplifies deteriorations of different durations, although it enables feasible utilization of these factors in multivariate logistic regression model and this same methodology is used in MET studies.[12–15] These limitations should be weighed against the strengths of this study. Aetiology was determined by autopsy for 55% of the patients. This percentage is exceptionally high as compared to other aetiologycal studies and autopsy after an unsuccessful resuscitation attempt has been suggested as 'golden standard' for studies on the cause of cardiac arrest.[26,27] We used age-adjusted charlson comorbidity index as a continuous variable to take into consideration the possible negative effect of cumulative age-related comorbidity in our analyses.[24] Third, despite a single centre design, TAYS is one of the five tertiary referral centres in Finland providing the most advanced care and the general wards represent all major specialties and our study population was very heterogeneous.

Conclusions

In-hospital cardiac arrests on general wards are caused by cardiac reasons in half of the cases. Both cardiac and non-cardiac IHCAs are often preceded by vital dysfunctions and subjective antecedents. Subjective antecedents, such as 'chest pain', are more common among IHCAs of cardiac aetiology. In case of an IHCA on a general ward of the hospital, low comorbidity, witnessed/monitored arrest and shockable primary rhythm are factors independently associated with better long-term survival.

Conflict of interest statement

Authors declare no conflicts of interests.

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