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Technical feasibility and ambulance nurses' view of a digital telemedicine system in pre-hospital stroke care – A pilot study

Anders Johansson[a,b], Magnus Esbjörnsson[c], Per Nordqvist[b], Stig Wiinberg[b], Roger Andersson[a,b], Bodil Ivarsson[a,d], Sebastian Möller[a,b,*]

[a] Office of Medical Services, Department of Clinical Sciences, Lund University, Sweden
[b] Office of Medical Service, Region Skåne, Sweden
[c] Department of Internal Medicine, Hässleholm Hospital, Sweden
[d] Department of Cardiothoracic Surgery, Lund University and Skåne University Hospital, Sweden

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ABSTRACT

Background: High-quality telemedicine in cases of suspected stroke has comparable precision with on-site medical examinations. A novel technical concept was developed in order to deliver a video/audio system to achieve more efficient patient assessment and diagnostic support.
Aims and objectives: The aim of the present pilot-study was to evaluate in a clinical setting the quality of a linked image and sound transmission in the prehospital assessment of patients with suspected stroke. In addition, we wanted to elucidate how ambulance nurses experienced the use of this innovative technology.
Design: The study used a quantitative method using questionnaires with fixed response options, combined with a qualitative approach to assess complementary statements of prehospital emergency care nurses (PEN) that had used the system.
Methods: The study was conducted in one ambulance care office and one hospital in southern Sweden. Six PEN and one neurological specialist (Dr) expressed their perceptions based on 11 cases with suspected stroke. Responses were assessed in the dimensions of the technology (Dr – image quality/sound quality; Dr and PEN), safety, sense of increased control and uniform assessment. A questionnaire technique was used, complemented with a qualitative part of the content analysis (PEN views).
Results: In the technology dimension, the Dr evaluated the image quality as Very good to Good (100%) while 75% of PEN answered that the digital stroke concept felt reliable to use and the digital stroke assessment is believed to increase uniform assessment. Asked if the present digital concept should be further developed and if further digital systems should be developed in general, the PEN were split in their responses (50 vs 50%), which could be related to a conception of unclear efficacy of the concept. Descriptions of the decisive comments emerged in three categories; *Minor operating interference, Physician's competence crucial* and *Unclear efficacy*.
Conclusion: All respondents seem to have confidence in the assessed digital stroke concept. The image quality is perceived suitable in the assessment situation but the nurses expressed ambiguity about the efficiency of the entire concept. The ambulance nurses also highlighted the physician's skills and personality as important factors for further development of the concept.

1. Introduction

Specialized stroke expertise is often required to facilitate delivery of advanced therapies. Access to this expertise is often limited but telemedicine has been proposed as a suitable method in a cost-effective manner, especially for geographically remote areas [1]. In acute stroke, the clinical symptoms together with the results of the radiological examination of the brain determine the type of treatment that is most appropriate. Since acute stroke treatments are strongly time-dependent, shortening the time to a correct physician assessment may improve patient outcomes.

Previous studies have shown that using high-quality telemedicine in stroke cases is feasible and has already impacted local stroke care [2]. In addition, findings by Demaerschalk et al. [3] support the hypothesis that stroke telemedicine consultations, compared with telephone-only, result in more accurate decision-making.

* Corresponding author at: Office of Medical Services, Lasarettsgatan 37, 221 85 Lund, Sweden.
E-mail address: Sebastian.strunk-moller@med.lu.se (S. Möller).

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Recent data from several randomized and controlled trials of mechanical thrombectomy in acute ischemic stroke have clearly demonstrated efficacy and strong benefit for appropriately selected patients [4–8]. In an unselected cohort of patients with a raised suspicion of stroke prehospitally, the proportion of eligible patients with large vessel occlusion (LVO) accessible for thrombectomy has been reported to be slightly less than 5% [9]. It is thus crucial to strike the right balance to avoid unnecessary over- and undertriage to thrombectomy centers in order not to diminish the overall positive effects at group level. At present, prehospital stroke scales have not been validated for identification of LVO, and retrospective studies have consistently demonstrated either a lack of adequate sensitivity or specificity, which highlight the need for more effective instruments for stroke triage, especially regarding selection for thrombectomy.

Here we report the development of a digital system, intended for a linked image and audio transmission from a patient within the ambulance vehicle while traveling. The system complements the current prehospital assessment tool PreHAST [11], used by prehospital emergency care nurses (PEN) in southern Sweden, with the more detailed National Institute of Health Stroke Scale (NIHSS), currently used in emergency room setting to guide the decision on thrombolysis/thrombectomy. As the NIHSS tool is based on visual assessment, image quality is a crucial parameter to provide both PEN and the receiving physician (Dr) in the emergency room with a better consultation support of stroke care with significant time gains, regardless of geographical location.

For successful implementation of this concept, different solutions may have to be further evaluated. Furthermore, since digital healthcare facilities are most likely to be developed and expanded it is, important to take the views of involved personnel into account, in order to develop successful implementation strategies.

The purpose of this study was to evaluate the quality of a linked image- and sound transmission in patients with suspected stroke diagnosis from an ambulance vehicle while traveling. The second purpose was to elucidate ambulance nurses' views of using this new technology.

2. Methods

2.1. Design

We developed a telemedicine application that provides video and voice transmission for medically intended use between an ambulance-mounted camera/audio system and computers at the hospital. This real-time system is based on a hybrid peer-to-peer and client-server architecture. The system aims to offer a more efficient stroke screening assessment and diagnostic support in patients with suspected stroke diagnosis in a pre-hospital context. In brief, the system consists of an ambulance unit equipped with 2 high-definition video cameras (Axis F1035, AXIS F44) and a sound unit (AXIS A8105) that are connected via a local TCP/IP network to a multi-channel modem (Viprinet 512N) (Fig. 1). The modem simultaneously uses 4 commercial cellular connections to communicate with a hospital base station (Viprinet Multichannel VPN Hub 1020) (Fig. 2). Prior to using the system in the study, we performed extensive testing of the final installation with simulated patients in the ambulance, both standing still and while travelling. At the same time the involved personnel was trained to use the system.

During the study, the system was used after the ambulance team first performed a PreHAST assessment, following current local guidelines for the management of suspected stroke. This test has been previously shown to be feasible for prehospital evaluation of neurologic symptoms in cases of suspected stroke [11]. When deemed eligible for inclusion in the study, the patient's consent was obtained and the PEN contacted the Dr to initiate a video consultation. Thereafter the Dr performed a NIHSS assessment remotely through the system.

Following the video consultation, the involved staff provided quantitative data by completing a questionnaire with fixed response options to assess the quality of image and sound. The response options were; *Very good*, *Good*, *Satisfactory* or *Deficient* in the assessment situation, and results are presented in absolute (n) and relative frequencies (%), based on a sample size of 11 clinical cases. The PEN's quantitative part of the questionnaire (question 1–12) used a three-point scale (*Yes, No or Don't now*, Table 1) and was complemented with a qualitative part (space to each question for comments) for content analysis. Prior to data collection, the questionnaire was tested on one professional ambulance RN (face-validity), and no corrections were made.

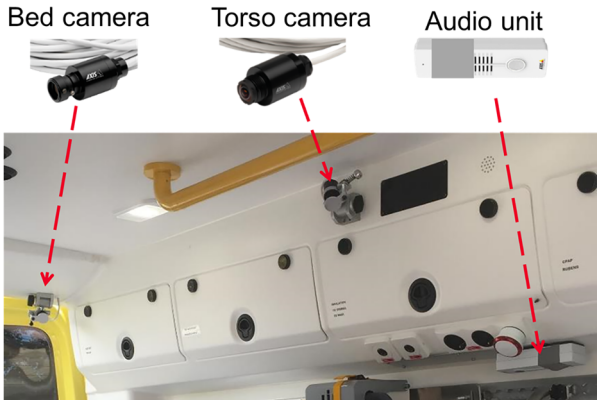

Fig. 1. View of video and audio transmission equipment installed in the ambulance. The design of the prototype was done in consultation with the involved physician and the ambulance staff.

2.2. Regulatory considerations

The video and voice call system was classified as Medical Device type 1. It's intended medical use is that of a medical video diagnosis system. It was developed and manufactured as a healthcare provider self-manufactured medical device for sole use in this study, in accordance with national regulations of the Swedish National Board of Health, that are based on the EU Medical Device Directive (MDD). Quality assurance and necessary documentation was done under the ISO 13485 compliant quality management system at MT Skane. The telemedicine system allows the physician to visually examine and assess a patient with suspected stroke in the ambulance while traveling. This information can be used to help and support a decision on triage to the appropriate level of care for the patient.

2.3. Data collection

The study was conducted in one ambulance care office and one hospital housing a Dr (neurologic specialist) in southern Sweden. The clinical evaluation phase ran during September/October 2017, with a total of 11 suspected stroke cases included in the study. The questionnaire part of the study was conducted between November 2017 and January 2018. A number of 4 professional ambulance nurses (PEN) expressed their assessments and comments confidentially. All informants had used the new system. Verbal and written information was given and consent was obtained from all respondents.

2.4. Data analysis and statistics

Demographic data (gender/experience year) of PEN were analysed using descriptive statistics and presented as percent (gender) and mean and standard deviation (SD) according to experience year. The quantitative part, using a questionnaire with fixed response options was analyzed with a non-parametric method and results are presented with median values. All statistical analyses were performed using SPSS statistical computing program (SPSS version 23.0).

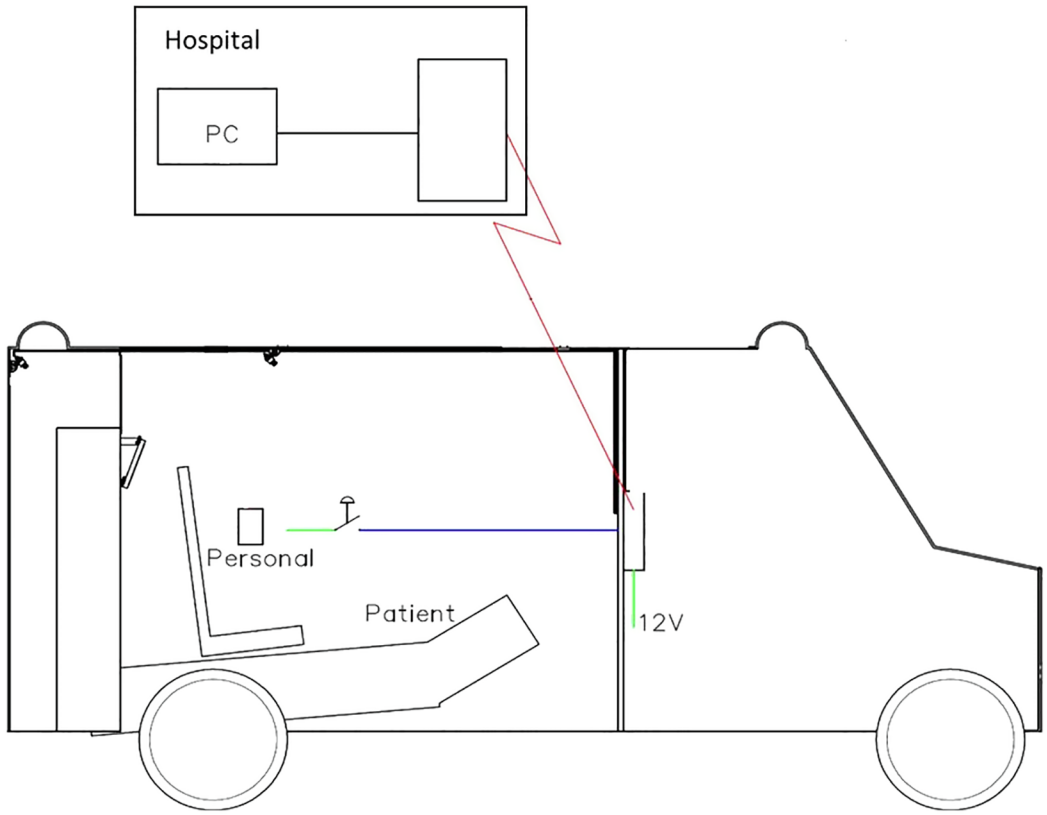

Fig. 2. Schematic overview of the system; cameras in the ambulance are started by the ambulance nurse and the video stream is connected via a server to the stroke physician at the hospital.

According to the qualitative analysis [qualitative descriptive method/content analysis (what pattern does it show?)], all authors read the open answers several times. After careful reading, descriptions of decisive comments were identified and classified according to different kinds of content into codes and categories. To ensure validity, all authors discussed the classifications until they agreed.

3. Results

A total of 11 cases of suspected stroke were included in the study and were assessed by one of three ambulance teams (4 ambulance nurses) that used the telemedicine system. The PEN informants had 10 ± 6 years of experience from ambulance nursing. The video system worked as expected in all cases and the Dr perceived the image quality as more than satisfactory in the assessment procedure (100% *Very Good* and *Good*), without the need for multiple assessment attempts. Only in one case, the sound was perceived *Deficient* (Table 1).

Descriptive PEN outcomes according to the fixed questions are presented in Table 2.

In the question (Q) concerning; *Do you feel that the digital stroke assessment concept feels reliable to use* (Q1), 50% of the nurses answered *Yes*, and 75% of the nurses expressed their perception of the concept as safe to use (Q2). In four statements about the informant's experiences concerning "*increased control*", "*make a more similar assessment*", "*shorter treatment times for patients*" and "*concept contributed to essentially positive response from included patients*" (Q3–6), the informants were more uncertain (Md 2, Fig. 2). Some informants expressed that in their view, the concept added no additional benefit to the normal assessment procedure since the patient receives the same assessment with NIHSS (Fig. 1), but highlights that the *Physician's competence is crucial*. According to Q7–8, the informants agreed that "*digital stroke assessment may increase uniform assessment*" (75%) and meet criteria for a "*patient safe care*" (100%).

The questions about if "*present digital system should be developed*"

Table 1
Clinical evaluation in 11 cases according to Sound and Video quality (6 nurses' vs 1 Dr). Response options; *Very good*, *Good*, *Satisfactory* or *Deficient* in the assessment situation. Result in absolute (n) and relative frequencies (%).

	Nurse n (%)	Dr n (%)
Image quality during video review		
Very good (clear picture without disturbance)	N/A	10 (91)
Good (single image disturbances without affecting the assessment)	N/A	1 (9)
Satisfactory (repeated image disturbances, multiple assessment attempts needed)	N/A	0
Deficient (no assessment possible)	N/A	0
Audio quality during video review		
Very good (clear sound without disturbance)	3 (75)	7 (64)
Good (single sound disturbances without affecting the assessment)	0	2 (18)
Satisfactory (repeated sound disturbances, multiple connection attempts needed)	0	1 (9)
Deficient (no communication possible)	1 (25)	1 (9)

Table 2
The distribution of the answer frequency in valid percent (Q1–10), with median values according to Yes = 1, No = 2 and Don't No = 3. Question 11 and 12 present median values from a Likert Scale (1 = dissatisfied – 6 = very satisfied).

			Don't know	Median values
Statements	Yes	No		
1. Does that the digital stroke assessment concept feel reliable to use (works stable)?	50	25	25	1
2. Does the digital stroke assessment concept feel safe to use (IT security)?	75	25	0	1
3. Does the concept of digital stroke assessment give a sense of increased control in the assessment situation?	25	50	25	2
4. Does the digital stroke assessment concept contribute to a more uniform assessment (based on treatment instructions)?	25	75	0	2
5. Is it your impression that the digital stroke assessment contributed to shorter time to treatment for patients compared to normal procedures?	0	75	25	2
6. Is it your impression from using the digital stroke assessment that this supplementary procedure has contributed to an essentially positive response from included patients?	50	0	50	2
7. Is it your opinion that digital stroke assessment may lead to a more uniform assessment of cases of suspected stroke?	75	25	0	1
8. Is it your impression that digital stroke assessment meets criteria for patient-safe care?	100	0	0	1
9. Do you want to see a further development of the digital stroke assessment project?	50	50	0	1.5
10. Is it your opinion that digital assessments are something we should continue to develop?	50	25	25	1
11. In general, how satisfied are you with the collaboration with the stroke-physician/ambulance team?				5.5
12. How satisfied are you with the introduction/training you received from the digital stroke assessment project?				5.5

The closed- and Likert Scale questions were analyzed for ordinal data variables.

(Q9) and if they wish to further see a "*development of digital systems in general*" (Q10), the informants were ambiguous (50 vs 50%). They expressed an *Unclearness* about the concepts *efficiency* although the informants were satisfied with the "*collaboration with physician*" (Md 5.5; Likert scale 1–6, Q11), and pointed out the importance of the physicians' skills and personality. All informants seem to have had an "*adequate introduction*" before the pilot study (Q12). Finally, three categories; *Minor operating interference, Physician's competence crucial* and *Unclear efficiency* emerged from ten codes (Fig. 3).

4. Discussion

Our initial results suggest that the introduction of telemedicine into the existing process allows the Dr and the PEN ambulance staff to create a care-team with a healthcare relationship with the patient. The present innovative audio/video system worked well from a technical perspective with just minor sound issues and we therefore believe that the concept has the potential to contribute to a more efficient patient assessment and diagnostic support in the management of suspected prehospital stroke cases.

However, in order to further demonstrate the technical stability of the system and positive outcome for the patient, further studies with an increased number of managed cases are necessary. In line with our results, the literature provides evidence that video assessment could improve the outcome of prehospital stroke care [12]; therefore, the next step should focus on broader implementation of the system. It is generally known that factors most frequently mentioned as impeding actual use are related to the technology itself (malfunctioning), handling (e.g. ease of use), relevance for patients and risks to patients [13]. Our present results confirm that ambulance PENs judge the digital stroke assessment concept reliable and safe to use. Professionals in another telemedicine area (telephone consultation) have expressed concerns about the use of telemedicine e.g. with regards to availability and increased workload, change in working methods and uncertainty about the digital tools and information security [14], but interestingly none of the respondents in the present study highlighted these issues. Therefore, valuable prerequisites for successful implementation of the concept in prehospital healthcare are present.

On the other hand, the informants were less certain about the concept's ability to increase control in the assessment situation and if the digital stroke assessment concept leads to a more accurate assessment. This view, however is in contrast to an earlier study that concluded that prehospital diagnosis and scoring of symptom severity has the potential to increase prehospital diagnostic accuracy in acute stroke care. The same study also indicated that digital concepts in rural areas, together with a prehospital uncertainty about a stroke diagnosis, can lead to faster evaluation and treatment from a neurology specialist [12]. A reason for the contradicting perceptions in our study could be that the PEN received a less detailed introduction to understand how the early stroke evaluation may contribute to a favorable outcome for the patient.

Whether or not the concept contributed to essentially positive reactions from included patients the PEN's had different opinions. Fifty percent of the respondents answered *Yes*; from previous studies it is known that patients, according to nurse assessments, are often pleased to receive a doctor's consultation, something that the nurses in our study could have been identified, but not commented upon [15]. Even according to the informant reflections, if the present digital system or digital systems in general should be further developed, the informants were scattered in their opinions. It has previously been concluded that direct involvement of professionals in the development of digital systems greatly enhances their acceptance and adoption [16]. Experience suggests that successful implementation in one area of care does not necessarily lead to rapid and simple adoption in other areas [17]. The result of the present study confirms this in the statements by PENs.

Overall, we believe that videoconferencing allows the patient, the ambulance team and the hospital physicians to interact visually and audibly, which should enable a more comprehensive communication to make faster definitive recommendations regarding diagnosis, therapy triage and/or other time-critical interventions [9]. In addition, there is compelling evidence to suggest that certain items on the NIHSS are highly predictive for large vessel occlusion, thereby facilitating identification of patients eligible for thrombectomy [10]. Since our system offers the opportunity to obtain NIHSS scores earlier in the process (i.e. already during transport), valuable time could be saved by supporting a thrombectomy/thrombolysis triage at an earlier stage. This indirect beneficial effect for patients would be of particular importance in areas where not all hospitals can provide thrombectomy, necessitating prolonged transport without thrombolysis, which has to be weighed against possible gains by earlier thrombectomy. Moreover over-triage to endovascular stroke centers could be reduced.

We think, that for successful implementation of the concept of telemedicine is important to defining the types of diagnoses (situations) suited for digital video practice and to develop acceptable policies with regards to the confidentiality of information exchange. In addition, it is important to improve the knowledge of the providers of care in order to gain acceptance of the concept. For example, the addition of a two-way videochat capability may promote nurse-to-physician interaction, build trust among providers to change attitudes and increase utilization and could therefore have a meaningful impact on reducing the burden of stroke disabilities [12].

Description of a decisive comments	Codes	Categories
Q1. "There was sometimes poor sound quality"	Affected sound quality	*Q 1-2.* ***Minor operating interference***
Q2. " Could be activated without ambulance crew knowledge"	Spontaneously activated	
Q4. "We do the same examination as the physician"	Double examination	
"Receives the same assessment with NIHHS",	Similar assessment as with instruments	*Q 4.* ***Physician's competence crucial***
"Will depend on the skills of the doctor"	Depending on skills	
"We do the same assessment anyway"	Add nothing to the assessment	
Q5. "Maybe we save a minute, but the big loss of time is on X-rays"	Unsure about time-saving	
"Results in double assessment, first in the patient's home, late in the ambulance"	Concept entails a double assessment	*Q 5, 10 & 12.* ***Unclear efficacy***
Q10. "Improve the X-ray procedure"	Uncertain effectiveness	
Q12. "Completely dependent on whoever works as a stroke jour"	Personality dependence	

Fig. 3. Summary of the analysis process.

5. Strengths and limitations

Clearly, the relatively small sample size both in terms of number of cases and informants in our study is a limitation. However, the study does includes all cases during the time frame when the digital video concept was used and all informants that were involved responded to the questionnaire. The methodical process of analysis increased the credibility of the interpretation study through the fact that the coherency of interpretations were discussed and revised by all authors. We also believe that the answers to the questions are genuine and of certain importance to the informants because the informants clarify their positions in free comments. However, the interpretation of qualitative results has a subjective component and it is up to the reader to evaluate the transferability to other situations.

Nevertheless, the area must further be researched since digital healthcare facilities are most likely to develop and expand and it is, therefore, important to take our results into consideration to guide of future successful implementation strategies in this field.

6. Conclusions

The current study presents a telemedicine system that allows the use of commercially available components and 3G/4G networks for the purpose of an early assessment of patients with suspected stroke, without introducing additional delay before transfer to the hospital. Apart from minor technical interferences, the system proved to be reliable and fulfilling the requirements of its intended use in a real life setting.

Moreover, our study provides a deeper understanding beyond the overall positive view of involved personnel on the use of telemedicine. In particular the PENs voiced questions with regards to the concept's efficiency or their notion of the physicians' skills and personage as crucial for the concept's success. These issues should be addressed to allow for an efficient implementation.

Further studies are thus needed to develop the concept further in order to make it suitable for a broader implementation. Their design should also shed more light on the potential medical benefits of telemedicine, in order to provide quick and appropriate care to as many patients as possible, even outside densely populated areas and large cities.

Declarations

Ethical considerations: Following review by the regional Ethics review board (Dnr 2016/893), this study was not considered subject to ethical approval under the Swedish legislation regulating research ethics. However, confidentiality and personal integrity were preserved in the study on several levels. The study protocol was approved by the involved department heads and patients had to give their consent to the use of the videosystem. Finally, informants and their managers were informed that information would be kept confidential and that they could withdraw at any time with no explanation. The submission of written answers to the questionnaires was considered as informed consent from participants. The first author held the key to the study participants' identities, all collected data were stored secure, accessible to the research team only.

Availability of data and materials: The data generated and/or analyzed during the current study are not publicly available to protect personal integrity of the informants, but are available in redacted form from the corresponding author on reasonable request. Supplemental data from connectivity tests conducted during development, are publically available as a "data in brief" article.

Competing interests: The authors declare that they have no competing interests.

Authors' contributions: AJ contributed to the design and analysis of the interviews; ME contributed with medical expertise to overall design and conduct of concept, study and data collection; PN and SW contributed to the regulatory package and risk handling; RA contributed to the technical solution of the system; BI contributed to the design and analysis of the interviews; SM contributed to overall design and conduct of concept, study and data analysis. All authors contributed to the writing of the manuscript and all authors read and approved the final manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ienj.2019.03.008.

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