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ORIGINAL PAPER

Telemedicine utilizing video streaming in prehospital assessment of stroke - an opportunity to shorten time to thrombectomy

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Abstract

Purpose In stroke, time and choice of treatment are critical. In ischemic stroke current options are thrombolysis or thrombectomy, with the latter as preferred choice in LVO (Large Vessel Occlusion)– but also only available at selected hospitals. If direct transport in suspected LVO can be decided with good precision in the ambulance, valuable time to treatment can be saved. Today this decision is far from obvious. Phone calls to stroke consultants and/or prehospital assessment scales are what´s commonly available. However, these introduce a risk of uncertainty and unfamiliarity in the assessments. With ViPHS (Video support in PreHospital Care) the purpose is to propose and test a telemedicine solution utilizing video streaming to increase precision in prehospital decisions regarding LVO cases. The paper presents the bearing clinical as well as technical principles and arguments in ViPHS, together with experiences gained from realistic full scale simulations and operational clinical pilots.

Method The project followed a clinical process innovation model developed by the project team. This four-step model involves analysis of present care processes and proposals regarding alternative care process and technology, stepwise prototyping leading into full-scale realistic simulations, and finally a limited and an extended pilot.

Results ViPHS has been tested in simulations and pilots. The results show that streamed video in the ViPHS telemedicine care model enables stroke experts to remotely make neurological assessments according to the NIHSS (National Institute of Health Stroke Scale) protocol.

Conclusions Streamed video and remote NIHSS assessment using ViPHS care model can contribute to shortening vital time to thrombectomy through more informed transport and care decisions for suspected LVO cases. The remote NIHSS assessment can also shorten time for other patients on arrival to any hospital with stroke handling capabilities like thrombolysis. Therefore, ViPHS constitutes an important addition to present acute regional stroke care. ViPHS may also be deployed outside ambulance settings, for instance at smaller care facilities, but also in non-stroke applications if customized care processes and on-call routines are designed accordingly.

Keywords Telemedicine · Stroke · Video-streaming · Thrombectomy · NIHSS · LVO

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1 Introduction

1.1 Overview and clinical background

In acute stroke, time to and choice of treatment are critical factors for the medical outcome, and thus the individual's continued life. In case of ischemic stroke, which makes up the majority (85%), the current treatment options are thrombolysis, which in Sweden is given at most emergency hospitals (69) or thrombectomy in a limited number of hospitals (8) [1, 2] across the country. In both cases, time for treatment is a crucial factor and delays in the care chain must therefore be minimized. The proven effectiveness of thrombectomy has also put further emphasis on the improvement of the stroke care chains - both in hospital and prehospitally [3].

An important component of the care is the prehospital intervention that most stroke patients first meet, and the choices made here regarding treatment strategy and destination. If it is already at this first stage possible to determine *with good precision* whether the patient is likely to be eligible for thrombectomy, a decision can be made on direct transport to hospital with thrombectomy facilities. It is desired to "*choose the correct destination at once"* and avoid the delay that occurs when transporting to the "wrong" hospital in cases where secondary transport to thrombectomy is the result of examination and assessment. In direct transport, a significant time gain can be achieved– estimated at 1–2 h alone in so-called DIDO time (Door In/Door Out) at the first hospital [4–6]. By adding the estimated extra transport time for this "detour", the total time delay can end up around 1.5–3 h in estimates based on a representative targeted region. Since the positive effect of thrombectomy on medical outcome (e.g. mortality, need for rehabilitation, independent life and remaining health issues) is estimated to double for each hour shorter time to treatment, transport delays may have a major impact on outcomes and costs to society– in addition to perhaps a life-changing difference for the individual [7, 8]. As a consequence of this estimated treatment effect there will also be a larger expected effect the earlier a given time saving can be gained. In a decision, current guidelines must also be considered. In Sweden thrombolysis treatment should be started within 4.5 h and thrombectomy within 6 h from onset - but in some cases even up to 24 h.

Deciding in the prehospital setting on direct transport with good precision is today far from obvious with the general means available– there is nothing as obvious as a 12-lead ECG in the event of an AMI (acute myocardial infarction) to rely on, for example. Phone calls to stroke consultants on-call and/or prehospital adapted stroke assessment scales are what are commonly used. However, there is a significant risk of uncertainty and unfamiliarity in these assessments, and thus a risk of both over- and undertriage [9].

Since early identification and treatment of stroke is such an important and well known challenge there are of course various strands explored to improve the situation in various ways. One of these is to introduce Mobile Stroke Units (MSU) in the prehospital setting [10, 11] to primarily reduce time to thrombolytic treatment but also support care chain optimization to thrombectomy. MSU are relatively expensive specially designed mobile units equipped with CT (computerized tomography), qualified communication facilities and specially trained personnel. The concept has a fairly long history including operational use in e.g. Germany and the US, but it has not gained wider use so far. Due to the costs, MSU have primarily been used in larger densely populated areas where stroke cases become frequent within a limited geographical area. In addition, there are also various diagnostic, and therapeutic, options being investigated and discussed with potential to improve the prehospital care provided– biomarkers, ultrasound and microwaves are some examples but none of these has entered clinical praxis [3].

With ViPHS (Video Support in the PreHospital Stroke Chain) the primary goal is to design an affordable prehospital care solution that *with good precision* support decision making on whether a patient is likely to be eligible for thrombectomy, and thereby direct transport to a hospital with thrombectomy facilities. The solution should be possible to be used in standard ambulances and handled by ordinary ambulance crews. Furthermore, it should be applicable in densely populated areas as well as semirural and rural areas where potential cases are widely scattered, and several ambulances are needed to fulfil the care demand.

The result is ViPHS where streamed video in a proposed telemedicine care model enables stroke consultants to remotely make a complete neurological assessment via the validated and in hospitals normally used NIHSS (National Institute of Health Stroke Scale) [12]. This can then contribute to a more informed decision on possible direct transport. But it will also act as valuable pre-arrival information to any receiving hospital in order to prepare for a quick planned internal care process.

1.2 Acute myocardial infarction and stroke have similar prehospital challenges– and solutions?

The early interventions in ischemic stroke show many similarities with AMI (Acute Myocardial Infarction), and the outcome of care for both is strongly linked to the time of treatment. For AMI, in parallel with the growth of thrombolysis as a treatment method [13, 14], telemedicine solutions were developed in the 1980s and 90s which enabled faster expert assessment at a distance. In Sweden and elsewhere new mobile communications allowed for nationwide transmission of ECG and other clinical and mission critical information from ambulances to hospital for real-time assessment. In Sweden MobiMed [15–17] was probably the first solution to be tested and introduced into clinical practice around 1990. Gradually, additional suppliers followed and today ECG from ambulances in case of suspected AMI is routine in the vast majority of ambulance organizations– e.g. MobiMed alone is currently stated to be present in around 2,700 ambulances worldwide [18]. This has helped to reduce mortality and improve patient outcomes. For example, a study shows that there is a 10% difference in mortality between direct admission to the "right" department and the patients who pass through the emergency department [19].

Initially in AMI, care routines were designed to prepare for arrival and optimize hospital flows. In the next step, routines were introduced where thrombolysis was initiated already in an ambulance on delegation from hospital doctors. During the latter part of the 90s, PCI (Percutaneous Coronary Intervention) came to be the preferred method given that it could be initiated within a reasonable period of time. Since the treatment could not be offered at all emergency hospitals, it became important to choose the destination, and telemedicine made decisions easier.

The development in stroke is similar but is displaced in time. Around the turn of the millennium, thrombolysis was introduced as a treatment and "save the brain" initiatives emerged to reduce delays in the care chain. In Uppsala, a pioneer in prehospital telemedicine, a routine was tested in the early 2000s [20]. The existing MobiMed was supplemented with stroke forms that were shared in real time with the neurology department. This meant that patients could be given a fast track to thrombolysis on arrival.

During the 2010s, thrombectomy gradually emerged, in analogy with PCI in AMI, as a treatment for large vessel occlusion (LVO) with the procedure limited to specific hospitals. This situation raised the question: can you find the "right" patients to transport directly to thrombectomy with sufficient precision while not risking increased transport time for those who benefit most from quick thrombolysis initially? Which method and strategy should be chosen– and do we have something as "simple" as ECG to find the right patients?

2 Method

2.1 Strategy and approaches

As can be seen from Table 1, no obvious tool such as ECG is currently available when it comes to prehospital stroke assessment. What is offered, in addition to vital monitoring, medical history and clinical competence, are assessment scales. Several of these have been developed and tested, but since they should be easy to learn, implement and remember, they are based on few observations. Not infrequently, they are not particularly well evaluated either. An important factor is also that despite the high incidence of strokes, it is not often that an individual ambulance care worker carries out an assessment. This introduces a factor of uncertainty that causes dispersion in the assessment. As an example, in a simulation study [9], it was demonstrated that there was a lack of knowledge among ambulance personnel on how assessment according to the regionally recommended mNIHSS, a simplified version of the well-established NIHSS assessment described below, should be carried out in practice.

Table 1 Comparison of treatment options and "tools" for acute myocardial infarction and stroke

AMI *"Time is muscle"*	Stroke *"Time is brain"*
Treatment options	
▪ Thrombolysis ▪ PCI (Percutan Coronar Intervention)	▪ Thrombolysis ▪ Thrombectomy
Prehospital "tool" options	
▪ 12-lead ECG - Well-known and documented - Can technically be handled by ambulance crew - Local automatic and/or remote expert interpretation	▪ Prehospital stroke scales - Several and simplified. Precision, documentation and user familiarity varies. - Can be performed by ambulance crew ▪ NIHSS - Validated, documented and well established in hospital use - Requires trained doctor. Can not be done by ambulance crew.
Telemedicine option	
▪ MobiMed (1986) and others since. Clinical "routine" since mid 1990:s	▪ ViPHS with NIHSS (Clinically demonstrated 2019)

The NIHSS (National Institute of Health Stroke Scale) [12] used in hospitals is a validated scale that could be used to achieve more reliable assessment. The Swedish National Stroke Report 2023 [18] writes: "*The use of NIHSS on arrival at hospital as a documented measure of stroke severity*, *is recommended for all patients as part of clinical routine*".

The disadvantage is that the NIHSS is complicated and requires experience in implementation and assessment. Consequently, NIHSS is difficult to teach and maintain at a good level in ambulance crews. But under the right conditions, it should be possible to do NIHSS remotely with video support and in collaboration between stroke consultants and ambulance. In that case, the combination of NIHSS and telemedicine is probably the best and most cost-effective tool/concept available today to be able to decide on direct transport in an ambulance organization. NIHSS, together with adapted care routines in hospitals and ambulances as well as a supportive technology solution, is therefore the foundation of ViPHS. In the national Swedish guidelines for stroke care in 2020, telemedicine was also introduced as a recommendation for prehospital care [22].

2.2 The project

The ViPHS project was initiated in 2015/2016 with the project PrehospIT/stroke [9] as an important background. In PrehospIT the acute prehospital stroke chain from alarm to hospital arrival was analyzed on the basis of, among other things, the desired information at the care chain's decision points. PrehospIT then proposed and demonstrated practically in realistic full-scale simulations how IT solutions from several suppliers, with the support of established standards, could interact and improve the chain, e.g. by adding historical "stroke-specific" medical record data from hospital ePR [9].

PrehospIT also clarified the benefits and clinical potential of an NIHSS assessment carried out early in the prehospital care chain. Thereby possible thrombectomy candidates could be identified and considered for direct transport to thrombectomy. The follow-up question then became - "how are we going to solve this in practice"? Train all ambulance personnel? Finding a technical solution? The answer was to develop the phone-based care routine for consultation with stroke consultant on-call that had just (2016) been introduced to also include streamed video.

The ViPHS project has followed a 4-step project model [23] developed within an established multidisciplinary network for prehospital research, development and innovation. Within this network, a "Team ViPHS" was established.

In the project model (Fig. 1), the first step involves process analysis and solution proposals regarding the care process and technology. In step 2, input from the previous step is used to design one or more prototypes which are developed and tested step-by-step into full-scale realistic simulations [24]. Step 3 involves testing the prototype in a limited clinical pilot. Step 4 in the model involves adaptation of pilot and results from stage 3 to a specific targeted operating environment, management organisation, and an extended pilot. The results in step 4 shall constitute the basis for decisions regarding introduction into fully clinical operations.

3 Results

3.1 What is viphs?

ViPHS is a "classic" telemedicine solution where the hospital expertise's knowledge is transferred and utilized in the pre-hospital setting via telecommunication. In ViPHS, four components are combined into a complete solution or care model:

1. Validated method for assessing possible large vessel occlusion (LVO); NIHSS.
2. Procedure for conducting NIHSS via telemedicine.

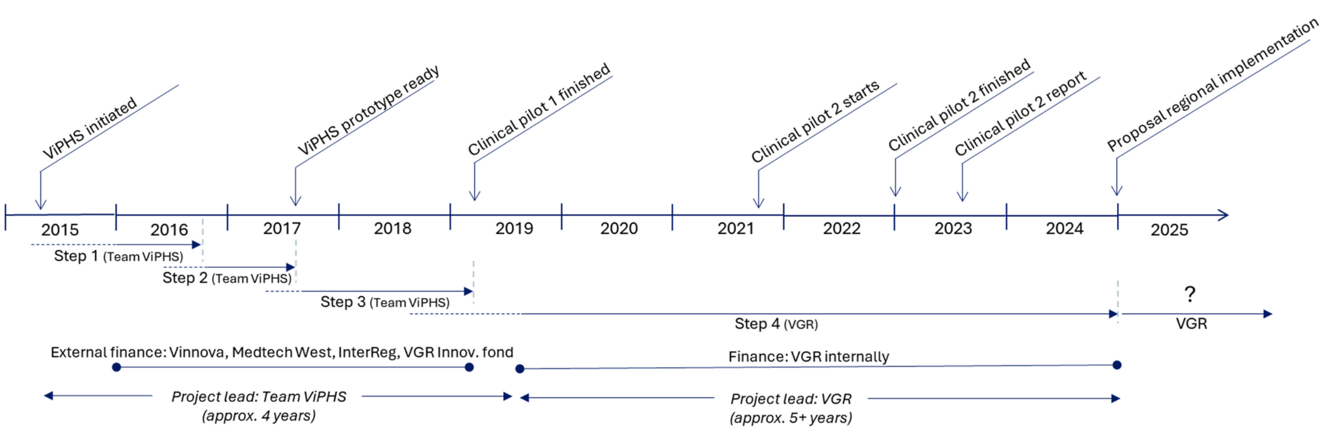

Fig. 1 ViPHS project timeline, milestones, steps in the project model and sources of funding

Fig. 2 ViPHS in the ambulance (image from simulation with actor as patient)

Fig. 3 ViPHS different camera positions (images from simulation with actor as patient)

3. Technology solution to support remote NIHSS assessment.
4. Customized prehospital care routine:

    a. Which patients should be consulted (distance, time, initial assessment, etc.)
    b. Routine in place; from arrival to transport decision.
    c. Back-up plan if consultation cannot be carried out.

3.2 Care routines and infrastructure

The basic working routine in ViPHS, which has been tested in simulations and pilots, is based on a "video addendum" to a care routine that was introduced already in 2016 in VGR (Region of Västra Götaland, Sweden). This routine governed consultation between ambulance and stroke emergency consultants over the phone. Therefore, ViPHS may be considered as a video enhanced telephone consultation enabling NIHSS assessment, improved collaboration between ambulance and stroke units, as well as a generally better assessment basis for care decisions [24].

Based on preliminary observations, the time required for NIHSS, when communication has been established, is estimated to be 5–10 min [25]. This should be put in relation to estimated time savings of 1–3 h depending on the pick-up location as well as variations in DIDO [4–6] and extra transport time.

When using ViPHS both the ambulance personnel and stroke consultants experienced significant benefits from video consultations instead of phone calls. The only objection from the ambulance personnel was the potential risk of losing patient focus during the consultation [25].

To implement the NIHSS "from a distance" assessment, three fixed cameras are used in the ambulance (Figs. 2 and 3). These are via a local video-server connected to a mobile network router enabling Internet access. The placement of the cameras has been tested in prototypes and simulations and then confirmed in an operational clinical pilot. The ambulance cameras show the patient from a side view, a view from the back and a face view from the ceiling (Fig. 3). This fixed installation provides a uniform, standardized and familiar solution that means a more efficient

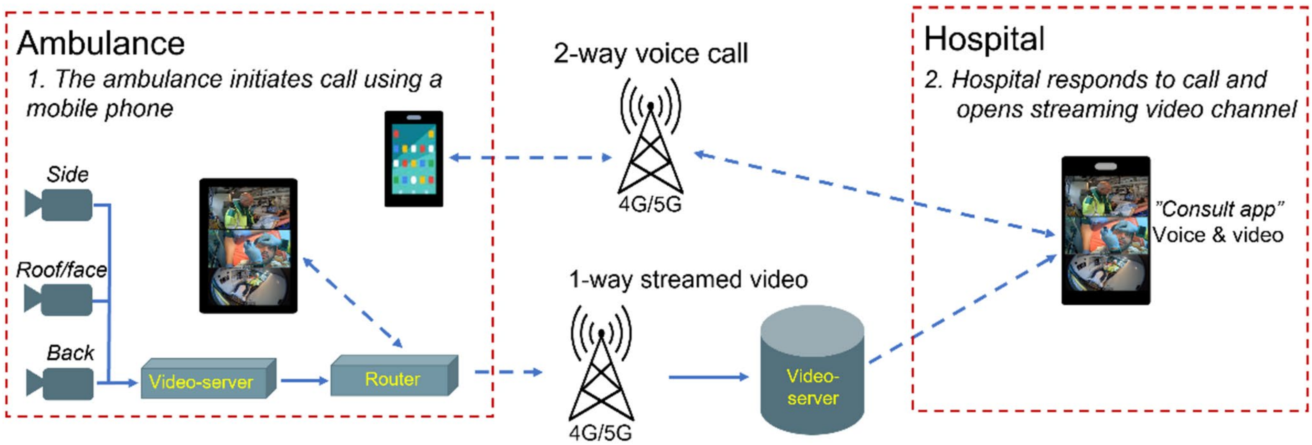

Fig. 4 ViPHS system structure and the two steps of the consultation process

and safer care process in ambulances and hospitals. For the individual users, ViPHS is not that commonly called for, and thus simplicity and recognizability are necessary just as an optimization for the NIHSS assessment procedure– the key in ViPHS.

ViPHS utilizes two mobile communication channels. In one, the ambulance contacts the stroke consultant on-call by phone (Fig. 4) in the same way as in the already existing routine relying solely on voice consultation. This channel continues to be used for speech throughout the consultation session. When the stroke consultant is ready to assist, the ViPHS video app is opened by the consultant and via the app the current consulting ambulance is selected (Fig. 4) and a separate channel for streamed video is established. In the app, the stroke consultant can select and change views, as well as zoom in with a "tweezer grip" (Fig. 3). In the ambulance, it is possible to take part in the same video as the stroke consultant. This facilitates dialogue but also provides the opportunity for local ambulance testing and training without involving hospitals.

During a consultation, no video or audio is saved. The ViPHS consultation is handled in the same way as the already familiar telephone consultation. A note is made in the medical record that consultation has been carried out.

3.3 Simulation and pilots

In the full-scale realistic simulations, step 2 in the project model, actors simulated two predefined typical stroke-patients in a process from incident site to ambulance and video consultation with stroke consultants at a distance, ending in a joint decision on the most appropriate transport destination [21]. Four ambulance teams (8 individuals) and 4 stroke consultants took part in the simulations [24–26]. The clinical pilot, step 3 in the project model, ran for 12 months in 3 regular ambulances. The step 4 pilot included 12 video-equipped ambulances covering a larger geographical area and operated for one and a half years. The results from both operational pilots are still analyzed and will be presented in separate papers. Preliminary data indicates that ViPHS was well received by care personnel and utilized as recommended in the local care guideline/protocol including ViPHS as a consultancy option.

4 Discussion

With ViPHS, there is now a proposal for a cost effective pre-hospital telemedicine solution with the potential to address the issue of being able to " *choose the correct destination at once* " in case of suspected LVO in stroke. It can be used in standard ambulances and by regular crews. Thereby it can contribute to a more informed decision on possible direct transport, but it will also act as valuable pre-arrival information to any receiving hospital to prepare for a quick and pre-planned internal care process.

ViPHS is also possible to apply to other applications where streamed video together with an adapted care process and acute "hotline" can play an important role. Designing and agreeing on care processes and hotline set-up is the key to success when going into operations– the technology is simpler and straightforward.

For stroke, ViPHS is currently tested in simulations and operational pilots in terms of technology and as a care model. Based on experiences, observations, completed and ongoing studies, and the reasoning that formed the basis for the design, the conclusion is that ViPHS today can constitute an important addition to acute stroke care.

Of course, more extensive operational experience would have been desirable to further confirm results and conclusions. In general, ViPHS has the same challenges as other similar telemedicine solutions, including MobiMed in the late 1980s when it comes to piloting. Although the number of possible patients is numerically large, they are spread over large areas. Therefore, many equipped ambulances, perhaps from several ambulance organizations, will be required to achieve the high patient numbers that enable e.g. comparative studies and statistics "with and without" ViPHS. In power calculations made within the project, it would be in the order of several hundred patients in each group (control and intervention). To gather such a material in a "reasonable" time, a test installation will in principle be equivalent to a major introduction both financially and organizationally.

Calculations with ViPHS implemented in a potentially targeted rural/semi-rural geographical region having a population of 8-900,000 inhabitants, show, for example, that with today's 70–80 ambulances, you can expect 2–4 consultations per ambulance and year and a total of around 200 consultations per year. In the extended pilot (step 4) with 12 ambulances in this area, about 25 consultations were estimated according to these figures. Preliminary the result indicate around 20, which seems reasonable since in practice never all ambulances were available 365/24/7. Estimates further indicate that approximately 90 patients per year would be identified and thus potentially be able to be transported directly within this population. In addition to patient benefits, this is also expected to result in significant societal savings [27, 28]. Detailed results from the operational pilots are under way, and will bring more insights into user experience, the number of consultations and the clinical decisions made. Preliminary data indicates that ViPHS seems to have been utilized for consultations in line with our estimates and expectations.

ViPHS like MobiMed and many other system-changing projects and innovations, where the technology is an enabler designed based on identified medical challenges, needs, issues and the state of knowledge, share the challenge that specific medical benefit research can be conducted only when the "tool" is in place. Therefore, it is reasonable that decisions on implementation are not made on "traditional" statistical data showing "with or without" data. Instead, decisions need to be made on premises such as successful simulations and pilots as well as indirect measures like knowledge of the importance of faster and more efficient care chains, the effect of different care choices and the somewhat undefined "clinical feeling and insight" or "gut feeling".

As part of ViPHS, a prototype for a mobile solution including care process for e.g. consultation from home has also been studied [29]. This option has been deemed unsuitable for stroke as potential patients normally show symptoms that, regardless of cause, require ambulance care. Unnecessary time should therefore not be spent here. It is more important to quickly get started with treatment and consultation in the ambulance with its familiar setting and then start transport as soon as the optimal destination is decided.

Although NIHSS is the best assessment tool currently offered, it has limitations. At a score above 15 the specificity is 95% and above 20 it is 99% [30, 31]. Therefore, the cases that end up correctly in the applied scoring limits are likely patients for thrombectomy, but there are individuals who are not found. In the research group work is ongoing to develop new complementary clinical decision support tools, including AI elements, to increase precision and find more patients [32, 33].

5 Conclusions

In conclusion, streamed video and remote NIHSS assessment using the ViPHS care model can contribute to shortening vital time to thrombectomy through more informed transport and care decisions for suspected LVO cases. It is a cost effective telemedicine solution and may be deployed on a large scale in standard ambulances with regular ambulance crews. The remote NIHSS assessment can also shorten time for other patients on arrival to any hospital with stroke handling capabilities like thrombolysis. Therefore, ViPHS constitutes an important addition to present acute regional stroke care processes.

ViPHS may also be deployed outside the ambulance setting, for instance at smaller care facilities, but also in non-stroke applications if customized care processes and on-call routines are designed accordingly.

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Data availability Not applicable. The manuscript presents a telemedicine and care model.

Declarations

Ethical approval The clinical studies/pilots using ViPHS referred to in the manuscript had ethical approval from the Regional Ethics Review

Board in Gothenburg (Ref. No: 2018-06-18 and 2020–05806).

Consent to participate Not applicable. The manuscript describes the design and implications of a new care model and doesn't directly include any participants.

Consent to publish Authors agree to publish the manuscript.

Competing interests The authors declare no competing interests.

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