KSP21PD – do not remove this tag

AI-supported decision making in emergency medical calls using speech recognition and structured hospital data

Relevance to the call

Norway has 16 Emergency medical communication centres (EMCC), staffed mainly with nurses answering all calls to the national medical emergency number 113. They are the first point of contact for almost every medical emergency, and within very short time, they have to detect time critical conditions and make decisions regarding life and death for the patients calling. This is a complex and sometimes very challenging task, and the only decision support available for the EMCC-staff, is The Norwegian Index for Medical Emergencies. This is a symptom-based, question-driven book from 1994/2017, leaning solely on the operator asking questions and processing information given by the caller.

The aim of this project is to develop a supplementary novel decision support framework for faster and more accurate recognition of time critical conditions in emergency medical calls, combining state of the art AI-based technology with existing innovative IT-technologies. We believe that we can significantly improve today`s system through real-time combination of already recorded systematic hospital data about the patient and live speech analysis, giving the EMCC-operators supplemental decision support for a given condition.

This interdisciplinary project will utilize the pervasive and transforming effects of AI, to meet societal needs and societal goals of sustainability and responsibility. Addressing the need for reducing variability in healthcare services (especially the emergency medical system, EMS) is an important feature of the project, relevant for health care providers both in the region, nationally and internationally. Developing innovative decision support in this setting is urgently needed, and AI-technology may contribute significantly to meeting this challenge.

Using inquiries regarding acute stroke as a proof of concept, we will demonstrate a novel and efficient way of identifying selected acute medical conditions (e.g., sepsis and acute myocardial infarction) in an emergency call setting. By utilizing the expertise of the applicants within the fields of emergency medical services, machine learning, statistics and hospital data architecture, we will create a system that can support the EMCC-operators in their evaluation of what measure is required in a better way than today`s system.

There is limited research on the quality of Norwegian EMCCs, but studies have suggested that performance can be improved, and Ellensen et al. found that the recognition of acute stroke symptoms was relatively poor. Thus, stroke is a suitable condition for demonstrating the value of AI as decision support, both since it is a relatively clearly defined condition, and because all patients are registered in the National stroke registry (NSR). Approximately 12.000 patients suffer from acute stroke in Norway every year, and less than half of them reach a hospital within the current treatment window for thrombolysis (4,5 hours). Stroke is also the third-leading cause of death, and the major cause of severe disability requiring long time care at institutions (50% will experience some degree of disability). Hence, in addition to the severe impact on patients and relatives, the societal costs are huge (estimated to approx. 10 billion NOK / year in Norway). If this project can make only a few more stroke patients reach hospital in time for effective treatment, the benefit will clearly outweigh the societal total costs, in addition to reduced suffering for patient and relatives.

The project will collect data from all stroke patients discharged from Helse Bergen in 2018 and 2019 from the NSR. These data will be linked to structured hospital data and the audio log from the EMCC-call concerning the patient. The EMCC-calls will be transcribed and inspected for speech patterns describing stroke symptoms in a non-medical way, using locally implemented (not cloud based) automated Microsoft Speech-to-Text cognitive services. Structured hospital information will be added, which represents an additional layer of information amplifying the analysis of the emergency calls in a novel way. This information will be used to train a machine learning model for predicting whether the patient is having a

stroke or not. The accuracy and speed of the system will be evaluated, first in “shadow mode”, followed by testing in a live setting.

1. Excellence

1.1 State of the art, knowledge needs and project objectives

Acute stroke treatment is highly time critical, with better outcomes the earlier treatment is initiated. This makes the diagnostic accuracy of EMCC´s handling of possible stroke inquiries essential. With today`s system, the EMCC-operator uses a paper-based triage system (The Norwegian Index for Emergency Medical Assistance), assisting them in asking relevant and necessary questions. Hence, the response will rely heavily on the individual operator`s ability to elucidate necessary information about the patient. The operators` access to historical hospital patient record information is very limited, and this reduces their ability to assess the patient`s risk profile. As only 60% of patients suffering from acute stroke calling the EMCC are correctly identified in the early phase, even a small improvement will have a substantial impact on both the individual patient, the relatives, and society in general.

An AI-based system making historical structured hospital data available for the EMCC operator, could greatly increase the identification of selected time critical medical emergency conditions. Given the technological solutions available, we regard the proposed project to be feasible.

Breakthroughs in AI, especially in the field of machine-learning, have made it possible to extract meaning and actionable information from complicated, heterogeneous data sets. This has led to astonishing results in computer vision, audio processing and analysis, natural language processing, and analysis of structured data. New machine-learning technologies have been introduced for decision support and prediction of patient outcomes in emergency medicine and critical care, often with humans in-the-loop. Examples of this are the use of relevant clinical, physiological and biochemical measurements to predict organ failure and mortality, length of hospital stay, and optimal resource allocation. Of particular relevance to the current project, systems for assisting emergency call-takers in the detection of out-of-hospital cardiac arrest using AI-based audio analysis have been constructed.

The suitable models and techniques are heavily dependent on high-quality curated data sets, and at the same time securing privacy and data protection. The computational infrastructure and frameworks necessary to design, train, validate and deploy the AI-models require a multitude of skills, including technical knowledge from software engineering, electronic patient record architecture and data engineering, and a solid grounding in the application domain.

The project aims to provide new and important knowledge, addressing the challenge of non-communicating and fragmented clinical information systems. Successful combination of structured and relevant patient data paves the way for real-time AI-assisted accurate prediction of acute illness.

Developing and implementing automated methods able to provide real-time reliable predictions is a fundamental component in providing high value of AI in emergency medicine. To have an impact the methods must be tightly integrated into the operational infrastructure. Such integrations are often difficult to implement and maintain due to technical limitations in the operational systems and acceptance of the users. There are several commercial product offerings that are based on establishing new workflows, often including data uploads to an external provider. However, these still operate outside the hospital infrastructure and the standard workflow, leading to issues related to privacy, capacity, cost and control. Participatory and tight integration with established infrastructure using open industry standards is a core objective of our project and is secured by the involvement of Helse Vest IKT.

Developing AI for live use in emergency medical calls is a new field, with relatively few groups investigating the possibilities. Previous work has not connected historical hospital data with what is being said in the emergency call live. This somewhat complicated process places high demands on us if we are to succeed, and it presupposes a tight collaboration between the AI competence, the medical expertise and the technical and statistical resources in the project. Although research on emergency medical dispatch and

communication is not very widespread, we will contribute to filling this knowledge gap, producing innovative work in the field of AI in emergency medical calls.
There are well-established general techniques, tools and frameworks for deep learning applied to speech recognition and analysis. To a large extent, several of the techniques have evolved from methods developed for computer vision tasks. Mohn Medical Imaging and Visualization Centre (MMIV) has a unique and internationally acknowledged position at the research front in developing decision support in the field of medical imaging using AI. Their methods and competence are translational to the current project, and building on this expertise in applying deep learning techniques, we will utilize and adapt state-of-the art methods to the project. MMIV has a wide international network of distinguished collaborators, which may add important input to the project.
After extracting the content of the call, we analyse the dialogue and interpret the words spoken by the caller. As the key-word-approach, representing the existence of key words in the analysed text is a convenient starting point for text analysis. It is not, however, the current state-of-the-art approach in natural language processing. Semantic analysis and related methods have replaced it, by representing the meaning of the text based on topic scores. Such methods analyse words in the text in context to each other, which can better determine the meaning of the text. The advantage of semantic methods in our project is clear. A keyword method would for example incorrectly recognize acute stroke if 'stroke' is spoken in the context of worry from the caller. Also, a keyword method will only classify calls correctly if the caller uses the correct predefined words, semantic methods can classify calls even when the caller does not use predefined words, and therefore fits better for analysing calls of non-medical professionals.

1.2 Research questions and hypotheses, theoretical approach and methodology

Primary objective:

Delivering fast (i.e., during seconds), accurate and robust decision support, based on a well-functioning AI-system capable of real-time identification of time critical medical emergency conditions (e.g., acute stroke) based on historical structured hospital data and live emergency call analysis. The aim is to improve sensitivity and specificity compared to today's system, which is based on manual assessment only.

Secondary objectives:

I) Implementing the solution in a large EMCC (Bergen).
II) Proving better real-time triage decisions in time critical medical emergency conditions.
III) Offer a non-profit nationwide spread of the system.
IV) Facilitate/prepare for using the solution in other time critical medical emergency conditions
V) Enable new possibilities for enhancing EMCC-operators` competence, improve the triage process, stimulate future research in the field, and automate documentation.

Research questions and hypotheses:

- Mapping and understanding of the pathways of patients, with a confirmed stroke diagnosis, from first contact with EMCC to stroke diagnosis in hospital, is necessary as a background for developing an AI-algorithm to support EMCC-operators in their recognition of patients with acute stroke.
- It is possible for a computer-generated algorithm, based on the combination of analysis of EMCC audio logs and structured systematized information already available from hospital medical records, to correctly differentiate stroke from other conditions, with a sufficient sensitivity and specificity.
- The sensitivity and specificity of EMCC operators´ recognition of acute stroke patients are significantly better with the new system than with the current, based solely on Index and the EMCC-operators´ individual skills.
- The new system, assisting the EMCC-operator, results in patients receiving more efficient and correct medical care.

Answering the above-mentioned research questions, will enable changing and improving today`s work-processes for better patient outcomes (as described in work package (WP) no. 6).

Methods:

To address the objectives and research questions, the project will be structured in work packages. Methods used in the WPs, are:

WP1: Characterization of stroke patients

A detailed examination of prehospital pathways and contacts with the EMS for every stroke patient in Helse Bergen and Haraldsplass hospital (2018 and 2019) will be performed. Patients will be obtained from the Norwegian Stroke Registry, which is situated at St. Olavs hospital.

From AMIS (Acute Medical Information System, the patient record in the EMCC) and the audio log from the 113-calls, we will manually map the patients` journey along a timeline. This will provide the basis for a graphic representation of the various pathways ("spaghetti plot"), producing detailed information on system delays, weak points, and other potential areas available for improvement. These results are demanded and useful, and will be widely published. This part of the project has already been approved by the Regional Committee for Medical and Health Research Ethics (REK).

WP2: Data retrieval and speech-to-text models based on historical data

Data from the stroke patients in WP1, will be linked to the structured hospital data and audio-logged EMCC-calls. These are the patient calls the AI-model will identify from the entire pool of emergency calls. To train the model, a random sample of patients without stroke calling 113 in 2022 will be selected as control group (see added description, page 14). Automated transcription from EMCC- calls will be used as the input, instead of the audio-files directly, as most calls are not coming from the patient itself, and to reduce complexity. For the automated transcription, we will test Microsoft Speech-to-Text cognitive services (implemented locally with no use of cloud-services). This will be one of the first AI- services used in Helse Vest. Nevertheless, the possibility for adding audio signals directly to the model may also be an option, although increasing the task complexity. As a result of WP2, we receive trainings data forour AI-model consisting of the patients (with and without stroke as a diagnosis) transcribed audio files and their available historical medical information.

WP3: Sentiment extraction and audio analysis based on historical data

This WP seeks to achieve high quality semantic analysis of the transcribed calls, studying speaking patterns and words used by the callers. This will construct representations that can be used for predictive models. We will approach this in multiple ways following schemes, as for example from the automatic dispatching projects in HVIKT: dictionary-based approaches and deep learning models for natural language processing. A dictionary in this context is a function which translates the input words into a machine-readable vector representation. For our project there are two promising techniques for building this dictionary, which we will explore.

The first technique, as for example word2vec, analyses all words in our transcript database with respect to the words around it and its meaning but without using information if the call was stroke related or not or any other hospital information.

The other technique, which is directly built into our prediction model, analyses all words in our transcript database with respect to the words around it and its meaning, but additionally takes into account if the call was stroke related or not and any other hospital information which is given to the model.

The goal of both techniques is to build a high-dimensional vector representation of each word, such that words which represent information of the same topics, as for example the topic stroke, are geometrical close to each other inside the constructed vector space. The final dictionary is then used to translate the calls into a machine-readable vector format, representing the meaning of the document in several topics.

Another approach we will investigate is to use large pre-trained transformer models as for example NorBERT. Transformers are a form of deep neural networks that have been shown to be particularly well-suited for a range of tasks in natural language processing, including text classification. We will use the representations encoded by transformer models to extract vector representations of the text.

As the meaning of a text may vary depending on the personal background of a patient, we will add structured hospital information from The Norwegian Patient Registry, such as any previous diagnoses, hospital admissions, lab results, and DRG-generating interventions, about the patient to our data. This additional layer of information amplifies our analysis of emergency calls in a novel way. The now available information relating to the call, summarized in a machine-readable vector, enables us to train machine learning models to predict whether the patient having a stroke or not.

The dataset used for training the models contains data from the years 2018/2019 and is therefore different from the evaluation dataset based on patients from the first half of 2020. A separation of the data into training, validation and test data assures that our trained model will not overfit to the data and that we can estimate the generalization performance, i.e., its ability to produce similar results on previously unseen, future patients.

The predictive abilities of the AI-based model will be compared to traditional statistical prediction methods, based on the same structured data sources as the AI-model, except audio analysis.

WP4: Testing on live-data and final adjustments
Given a successful evaluation in WP3, the performance of the AI-based decision support system will be compared to today`s individual EMCC-operator-based system during a period of approximately one year in Bergen EMCC. Initially it will run in shadow-mode, not available as decision support for the operators, (only the research group). Specifically, the accuracy and speed of the system in a live setting will be compared to the EMCC operators`. Afterwards, the interaction between the system and the EMCC operator will be tested in a live setting. This will enable us to evaluate to what degree the system is able to improve within the decision process of the EMCC operators in terms of sensitivity and specificity.
Developing and implementing automated methods able to provide real-time reliable predictions is a fundamental component in providing high value of AI in emergency medicine. To have an impact, the methods must be tightly integrated into the operational infrastructure. Such integrations are often difficult to implement and maintain due to technical limitations in the operational systems and acceptance of the users. There are several commercial product offerings that are based on establishing new workflows, often including data uploads to an external provider. However, these still operate outside the hospital infrastructure and the standard workflow, leading to issues related to privacy, capacity, cost and control. Participatory and tight integration with established infrastructure using open industry standards is a core objective of our project and is secured by the involvement of Helse Vest IKT.

WP5: Management, data protection and privacy
Throughout the project we will take care of all needs for protecting the individual`s data, according to legislations (GDPR, DPIA, Norwegian laws and regulations).

WP6: Dissemination of results (see section 2.2)
Challenges and risks:
This is an ambitious project with certain challenges and risks, and we have identified the following:

- *Lacking data availability and/or poor quality.* The historical audio files may be difficult to retrieve and connect with the hospital records may be challenging, and parts of the data may also suffer from bad quality. Consequently, the final dataset available for training may be reduced. In this case, including data from several EMCCs, and/or exploring techniques for generating synthetic data, may be a solution.

*Delayed access to patient`s personalia.* If the EMCC-operator does not gain access to the patient`s name/social security number at an early stage in the emergency call, the system will not be able to utilize historical hospital data. In such cases, only the speech recognition part of the model can be used. WP1 will give us information about the severity of this problem. Afterwards, it will be addressed in the modelling phase by careful performance testing of the model with and without additional hospital data. A possible solution can be to train a model without additional hospital data, which will be used during the call until additional hospital data are available. Then a model utilizing the audio files and the hospital data will be applied.

- *Poor performance of algorithms.* The classification algorithms may not demonstrate a sufficient performance in terms of separating acute stroke patients from other conditions. There can be several underlying reasons for this; most commonly due to; model being incapable of the task assigned, model being over-fitted to the training data, excessively high or low model complexity and bias in the data. Such potential issues will be explored and mitigated by using best practices within machine-learning methodology, such as using appropriate performance metrics, choice of model, cross-validation schemes, model parameter tuning, data exploration and regularization techniques.
- *Slow execution speed.* The final model to be operationalized within the system used by the operator may be too slow in providing a prediction score rendering it useless in a decision procedure. Care will be taken to use data readily available in a production setting. Furthermore, the complexity of the model may need trade-offs to reduce undesired latency in live scoring.

Success in endeavours aiming to unlock the potential of modern machine learning in healthcare is however of utmost societal importance, and we believe we have identified an area where we are well positioned for valuable innovation. If the system, however, should not prove successful, the project will result in a novel database of lay person descriptions of stroke symptoms in emergency medical calls provided through the training process of the machine learning model. This database would be of significance for future research and helpful for training medical professionals to improve communication with patients or relatives in these time sensitive situations. In addition, the project will map stroke patients` journey through the emergency medical chain, identifying areas suitable for improvement. This unique analysis will provide important and useful information for both health authorities and the public. Additionally, a state-of-the art AI-based speech-to-text solution for EMCC calls will be tested. If tested successfully, the implementation would be of great value not only for documentation purposes in emergency medicine, but also for future research.

Interdisciplinary considerations:

We are proud of having been able to compose a highly interdisciplinary project group with complementary skills in medical care (intensive-care medicine, anesthesia, stroke, and neurology), scientific computing (machine-learning, statistics, and mathematics) and information technology (deployment of data stream and algorithms, fast AI, real-time operation, IT-architecture, and integration of new algorithms within existing IT-systems).

The project group also has a user representative (former stroke victim and registered nurse) from LHL Hjerneslag, who is already engaged as a co-researcher.

Haukeland University Hospital will benefit from the project, because quality of services will be improved, and Helse Vest IKT as the IT-provider will be able to present new and groundbreaking service to their users (hospitals in the region). Gaining seamless access to already available structured hospital data may have a transforming effect on clinical decisions.

Ethics:

Firstly, the project will comply with The Declaration of Helsinki – ethical principles for medical research involving human subjects. Further, the use of AI in medicine is a relatively new field, and the development is to some extent faster than the legal and ethical regulations. The Norwegian Government has recently published a *National strategy for artificial intelligence*, where several relevant topics are highlighted. Developing AI as a clinical decision support tool, requires use of sensitive patient information. Thus,

approval from the Regional Committee for Medical and Health Research Ethics (REK) is necessary. Another challenge is the translation from research project to patient treatment. This may demand approval from the Norwegian Medicines Agency. Contact with the Data Protection Officer at Haukeland University Hospital is established, seeking advice on legal and ethical regulations (GDPR and DPIA). Leader(s) and employees at the relevant EMCC(s) will be informed and involved in the project.
Informed consent from the individual patient is hard or impossible to obtain in the acute phase. Stroke patients may suffer from language problems or cognitive deficiencies, making it justifiable to waive informed consent. We`ve already sent a passive consent letter to approx. 1000 patients from the NSR.
A known risk when using machine learning is bias against certain groups of people, e.g., gender, ethnicity, age or other characteristics, often embedded in the training data used to construct models. We are aware of the issue, and we will attempt to both study the issue and ensure that it does not influence the decisions made by the AI. Possible ways to ensure that the bias is kept to a minimum and that the resulting models are fit for their intended purposes, include using prudent splits of the data into training and test sets, as well as de-biasing methods aimed at removing unwanted features from the model's decisions.

1.3 Novelty and ambition

Machine-learning frameworks have been applied to non-emergency conditions, showing that a computer can assist with clinical decision-making or screening under certain circumstances. However, machine-learning technologies used to support clinical decision-making in an acute medical context is a new field (4). One study has shown that AI-system can improve the recognition of cardiac-arrest using the raw audio of the caller (5). This system does, however, not include additional data sources from the hospital records. Our ambition is to introduce system capable of simultaneously analysing what is being said by the caller and the available information about the patient from the hospital records. This represents a new and novel concept within both medicine and ICT engineering, representing a potential for development of new knowledge including theoretical, empirical and experimental advances in both areas.
More research on emergency medical communication systems in general, and decision support in particular, is needed. The current project will address several important aspects of the EMCC-decision process:

- Detailed mapping of the prehospital pathway of a large and representative group of acutely ill patients
- Introducing AI-based decision support in EMCCs opens for a novel and ambitious way of managing inquiries regarding such patients
- Applying a quality improvement approach to both EMCC-process (time) and -outcome (correct decision), since both issues are essential in emergency medicine

2. Impact

2.1 Potential impact of the proposed research

The potential academic impact of the current project is significant, as it represents a unique way of combining information already available in the hospital IT-system/patient record with real time voice recognition and analysis regarding an acute new health problem. This potential solution rests on cutting-edge technology and recent breakthroughs in other scientific fields.
In general, the public expects that the health care system takes advantage of up-to-date technological possibilities, utilizing already available data collected in the hospital IT-system/patient records. So far, this is hardly the case, and the project specifically addresses this gap in the emergency medical communication system, as mentioned above.
If successful, a new way of utilizing structured historical data in an emergency setting will be developed. Combined with real time audio analysis from the emergency call, this would be interesting for both industries, the health care systems, acutely ill patients, and society. Further, we think that the introduction of the system as a decision support tool in EMCCs in a follow-up project can be applied to other emergency medical conditions as well, such as e.g., sepsis and chest pain.

We firmly believe that introduction of this decision support tool in EMCCs will be useful for giving patients more efficient and correct help in the prehospital EMS, and thus ensuring correct treatment faster. This will have great impact on the patients' quality of life, as well as save substantial societal expenses.
Through exploiting the potential of the stakeholders, we hope our results can contribute to getting a step closer to The United Nation`s Sustainable Development Goal number 3; "Ensure healthy lives and promote well-being for all at all ages". The system will be freely available for interested parties, including to emergency medical services in low- and middle-income countries.

2.2 Measures for communication and exploitation of results

We plan to share our results, findings and the model developed widely, to all possible stakeholders, non-profit. The broadly composed group of resource persons from several fields, makes us able to reach out to both clinical and technological environments. In addition, we cooperate closely with a user organization with an important role in the project, to ensure dissemination to a broader public through their communication channels. Initially, we will arrange a kick-off for our stakeholders and collaborators. Milestone meetings will be arranged regularly, where the research group and the project advisory board discuss the project and its progress. When the project comes to an end and we have final results, we will invite all the involved organizations and contributors, as well as others who might be interested, to a final gathering and presentation. Throughout the project, we will reach out nationwide towards EMCCs and other relevant stakeholders:

- *Patients and their relatives:* Popular-science articles and information on relevant websites, as well as reaching out to patients and the public via social media and articles in national newspapers.
- *User-organisations: R*egular and updated information on their webpages and social media, articles in membership-magazines and other presentations on the user-organisation`s various arrangements/conferences.
- *Research community: R*esults will be published in international peer-reviewed scientific journals relevant, such as *Resuscitation* and *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, or JMIR Medical Informatics*. Further, the results will be presented in national and international conferences, such as *The European Emergency Medicine Congress*, *European Emergency Medical Services Congress, and KlinIKT*. In addition, we plan to present methodological solutions and findings of value for other researchers in cooperating institutions and organisations, as well as through information on our web pages (kokom.no). Finally, the results may also contribute to develop the educational student programs at the University of Bergen and Western Norway University of Applied Sciences (HVL).
- *Clinicians:* As AI in medicine is a rapidly growing science with several disciplines and research groups involved, our project also seeks to facilitate networking and mutual exchange of experiences between relevant actors in the field. Thus, we aim to invite an extended group of people involved in the same research field for mutual exchange of experiences and updates. These events will be scheduled two or three times during our project period and will hopefully stimulate further cooperation and development within this field of medicine, primarily in Scandinavia.
- *Policy makers and hospital leaders: P*olicy briefs, presentations at The Christie Conference at University of Bergen, e-HIN (e-health in Norway), and other national conferences targeting communication between researchers and policy makers.

3. Implementation

3.1 Project manager and project group

The project manager is Guttorm Brattebø, professor in traumatology and currently the CEO of KoKom with a significant record in intensive-care medicine and anesthesia. With 20 years' experience as the medical and operational director for Bergen EMS, he has a unique experience from state-of-the art emergency medicine. He will be responsible for leading the project, ensuring that it proceeds according to plan and keeps a high standard.

To reach the desired aims, we have composed a project team with highly interdisciplinary and complementary skills within the fields of medical care (emergency medicine, stroke, and emergency medical communication), scientific computing (machine-learning, statistics, and mathematics), and information technology and data architecture (deployment of data stream and algorithms, fast AI, real-time operation, integration of new algorithms within existing IT systems).
The project team is composed of representatives from a wide variety of organizations and research environments, depending on broad cooperation with several stakeholders. The team members from KoKom, Helse Vest IKT, MMIV, and Seksjon for Helsetjenesteutvikling (Helse Bergen) will perform the day-to-day development, implementation and integration of algorithms and routines.
Regular project meetings will ensure necessary progress, co-operation and required standards. The team has extensive project experience, incl. student supervision and team management, as documented in the attached CVs. To obtain historical data on patients from Haraldsplass hospital, we are cooperating with the data protection officer and technical personnel at this site.
For safeguarding a close anchoring and professional relevance for both users and the health care system in general, a separate project advisory board has been established:

- **Hanne Klausen** – PhD, director / consultant, Surgical services clinic, Haukeland University Hospital
- **Geir Sverre Braut** – PhD / consultant, Stavanger University Hospital
- **Tommy Skar** – Secretary general, LHL Hjerneslag
- **Steinar Olsen** - Department head emergency medical services, Norwegian Directorate of Health
- **Joe R. Aseerwatham -** Brukerutvalget Helse Vest
- **Øyvind Østerås** – PhD, director / consultant, Bergen Emergency Medical Services

Project team and collaborators, including work packages allocated to each member:

Name / institution	Expertise	Role	WP
Helse Bergen			
Guttorm Brattebø, professor in traumatology	The head of KoKom. 20 years' experience as the medical andoperational director for Bergen EMS, unique experience from state-of-the art emergency medicine	Project leader	1*, 2, 3, 4, 5*, 6*
Emil Iversen, MD	PhD-candidate, KoKom. GP with expertise in emergencymedical communication	Project team	1-6
Anders Strand Vestbø, PhD	Special advisor at the Section for Healthcare Services development. Integration of internal patient registry data and development of AI and machine-learning	Project team	3
Audun Lange	Special advisor at the Section for Healthcare Services development. Data architecture and patient record management.	Project team	
Annette Fromm, PhD / MSc (Stroke)	Clinical expertise in stroke, in-hospital data and supervision of PhD candidate	Project team	1, 4, 6
Lars Myrmel, advisor	Retrieval of audio logs and cooperation with Bergen EMCC.	Project team	1
(MMIV) / Western Norway University of Applied Science (HVL)			
Alexander Selvikvåg Lundervold, PhD, associate professor	Core competency in medically applied machine-learning approaches for development of novel AI applications. One of the PIs in the machine-learning research group at MMIV, "*Computational medical imaging and machine-learning – methods, infrastructure and applications*"	Project team	3*

Erlend Hodneland, PhD	Key expertise in mathematics, machine-learning, simulation tools, and scientific computing	Project team	
Øyvind Grutle	Master student at HVL. Speech to text.	Project team	2
Jens Andreas Thuestad	Master student at HVL. Speech to text.	Project team	2
Helse Vest IKT			
Christian Autenried, PostDoc, special advisor	Support and responsible for delivering pre- and in-hospital data from the Helse Bergen trust's systems, and contributing to integrated AI-development and deployment of data stream and algorithms	Project team	1, 2*, 3, 4
Mounir Haizoune, special advisor	Support and responsible for delivering pre- and in-hospital data from the Helse Bergen trust's systems and deployment of data stream.	Project team	2, 4
Konsulent Styringsdata	Support and responsible for extraction of data for control group. Create and keep in safe server the key for connection of data across systems.	Support	
Norwegian Stroke Registry			
Hild Fjærtoft, PhD, leader NSR	Delivering national data on stroke patients. Participating in data processing.	Collaborator	1
Kari Krizak Halle	Delivering national data on stroke patients. Participating in data processing.	Collaborator	1
Landsforeningen for Hjerte- og lungesyke, represented by LHL Hjerneslag			
Merethe Landaas	Leader of LHL Bergen and spokesperson for LHL Hjerneslag Ung Hordaland, user representative and co-researcher	Project team	1-5
Oslo University Hospital			
Hege Ihle-Hansen, consultant, PhD	Consultant and head of Stroke department. Clinical expertise in stroke, supervision of PhD candidate	Collaborator	1, 4, 5
Emil Iversen	Part time consultant Oslo EMCC	Project team	1-6
Helsetjenestens driftsorganisasjon for nødnett HF (HDO)			
Ingar Svingen	Team leader customer and application governance, technical interactions and user interface	Collaborator	2, 4

3.2 Project organisation and management

Work plan:

Work Packages and Tasks	2022				2023				2024			
	1	2	3	4	1	2	3	4	1	2	3	4
WP1: Characterization of stroke patients												
Task 1: With data from NSR: identify and collect data on stroke patients in HB in 2018/2019												
Task 2: Collect AMIS data according to list for the patients in task 1												
Task 3: Review audio logs for patients with unclear pathways												
Task 4: Extract relevant audio logs and information from hospital record system												
WP2: Data retrieval and speech-to-text models based on historical data												
Task 5: Create and test an automated method for identifying and retrieving the correct audio file from the audio log system in Bergen EMCC, and link it to the patient's hospital data												
Task 6: Link the data from NSR with the other relevant and structured hospital data and audio logs for all 50.000 113 calls, including audio logs.												
Task 7: Setting up AI system for speech-to-text recognition, reporting the spoken text.												
Task 8: Combining the heterogeneous data sources from task 5-6 into a structured dataset to be used for analysis and modeling												
WP3: Sentiment extraction and audio analysis based on historical data												
Task 9: Setting up AI system for sentiment analysis, scoring the caller emotional affect rate.												
Task 10: Setting up AI system for semantic analysis, understanding the meaning of the call.												
Task 11: Aggregating heterogeneous data sources from WP2 and task 10-11 and construct predictive models indicating stroke/non-stroke patient calls made by bystanders or relatives												
WP4: Testing on live-data and final adjustments												
Task 12: Decide the nature of the AI - human interface, and introduce the AI-based decision support tool to the EMCC staff.												
Task 13: Start-up, running, supporting and monitoring of the project until a given number of calls have been processed.												
Task 14: Analysis of the results from the prospective testing performed in task 13.												
WP 5: Management, data protection and privacy												
Task 15: The project leader will dedicate 20% of his position to this project.												
Task 16: Ethics-approval												
Task 17: Local agreements and cooperation												
WP6: Dissemination of results												
Task 18: Reach out towards several key stakeholders (see section 2.2)												

Allocation of WPs and tasks to project team members:

WPs & TASKS	WP LEADER(S)	TASK COLLABORATORS
WP1: Characterization of stroke patients	Brattebø, Iversen	
• task 1: With data from NSR: identify and collect data on stroke patients in HB and Haraldsplass hospital in 2018/2019.		Iversen, Myrmel, Fjærtoft
• task 2: Collect AMIS data according to list for the patients in task 1.		Iversen, Myrmel
• task 3: Review audio logs for patients with unclear pathways.		Iversen, Myrmel
• task 4: Extract relevant audio logs and information from hospital record system		
WP 2: Data retrieval and speech-to-text based on historical data	Autenried	
• task 5: Create and test an automated method for identifying and retrieving the correct audio file from the audio log system in Bergen EMCC, and link it to the patient's hospital data.		Myrmel
• task 6: Link the data from NSR with the other relevant and structured hospital data and audio logs for all 50.000 113 calls, including audio logs.		Autenried, Mounir
• task 7: Setting up AI system for speech-to-text recognition, reporting the spoken text.		Autenried, Mounir

• task 8: Combining the heterogeneous data sources from task 5-6 into a structured dataset to be used for analysis and modeling		Autenried, Mounir
WP 3: Sentiment extraction and audio analysis based on historical data	Lundervold	
• task 9: Setting up AI system for sentiment analysis, scoring the caller emotional affect rate.		Lundervold, Autenried
• task 10: Setting up AI system for semantic analysis, understanding the meaning of the call.		Lundervold, Autenried
• task 11: Aggregating heterogeneous data sources from WP2 and task 10-11 and construct predictive models indicating stroke/non-stroke patient calls made by bystanders or relatives		Lundervold, Autenried
WP 4: Testing on live-data and final adjustments	Brattebø	
• task 12: Decide the nature of the AI - human interface, and introduce the AI-based decision support tool to the EMCC staff.		Svingen, Iversen, Myrmel
• task 13: Start-up, running, supporting and monitoring of the project until a given number of calls have been processed.		Iversen, Myrmel, Autenried, Lundervold
• task 14: Analysis of the results from the prospective testing performed in task 13.		Iversen, Aβmus, Autenried
WP 5: Management, data protection and privacy	Brattebø, Iversen	
• task 15: Project governance and leadership (20%)		Brattebø
• task 16: Ethics-approval		Iversen, Brattebø
• task 17: Local agreements and cooperation		Myrmel, Brattebø, Iversen
WP 6: Dissemination of results	Brattebø, Iversen	
• task 18: Reach out towards several key stakeholders. See section 2.2.		All

The project is run from Haukeland University Hospital/HVIKT, to which all participants report. WPs and research activities will be coordinated and governed from the project leader, in close cooperation with the research group. The project advisory board will meet twice a year, monitoring progress and providing input to the project.
All participants are carefully selected, providing essential insights and experience for a successful project. Their research- and technical competence is a key to success. Furthermore, closely involving a user representative with insight and experience as a stroke patient and nurse, makes the project unique. This will be very useful in linking the solution to those who will benefit from it. Also, the Secretary General of LHL Hjerneslag and a representative from the regional hospital User Board in Helse Vest have accepted to serve as members of the project advisory board, contributing with their user perspective in this forum as well.

Clarification 30.01.23:
Research-responsible institutions:

- Western Norway University of Applied Sciences
- Oslo University Hospital
- Haraldsplass Deaconess Hospital

Collaborating institutions:

- University of Bergen
- The Norwegian Stroke Registry

Addendum 12.06.23 regarding control patients – corrected 05.02.24 (audio logs for the control group):

Within the project group, we have worked to refine and specify the selection of the control group, as this may influence REK's assessment of the amendment and the planned procedures. The selection process differs somewhat from the original plan, and we believe the revised approach better ensures data minimisation and protection of privacy. The points below describe how the control group will be selected and which data will be used in this process, including clarification of the need to listen to audio logs as requested by REK:

- One calendar year (2022) of calls to the Emergency Medical Communication Centre (AMK) in Bergen forms the basis for selecting patients for the control group.
- We will prepare a search in AMIS in which we exclude all patients under 18 years of age, all with criteria codes related to psychiatry, and all with criteria codes related to childbirth/gynecology.
- The AMIS data extracted will not constitute the final control group, but serve as the starting point for further selection.
- To select the final control group, we will link the AMIS dataset with structured data from the hospital electronic medical record. Personal identifiers will only be used for linkage and will be removed before the dataset is made available for analysis. We will not use audio logs for this step. Based on the exploratory analyses of journal data as described above, we will then select a final control group, for which all previously approved data sources will be used to train the AI model (prescription data, audio logs, hospital data).

We will inform the patients in the control group in accordance with REK's instructions.

Clarification 16.11.23:
Helse Vest IKT will be added as a research-responsible institution, as they will assist with extracting and linking data—via a linkage key stored in a secure environment at Helse Vest IKT—from AMIS and DIPS for the first control group. This first control group consists of all individuals who called 113 during one calendar year (with excluded groups removed, including patients under 18 years).

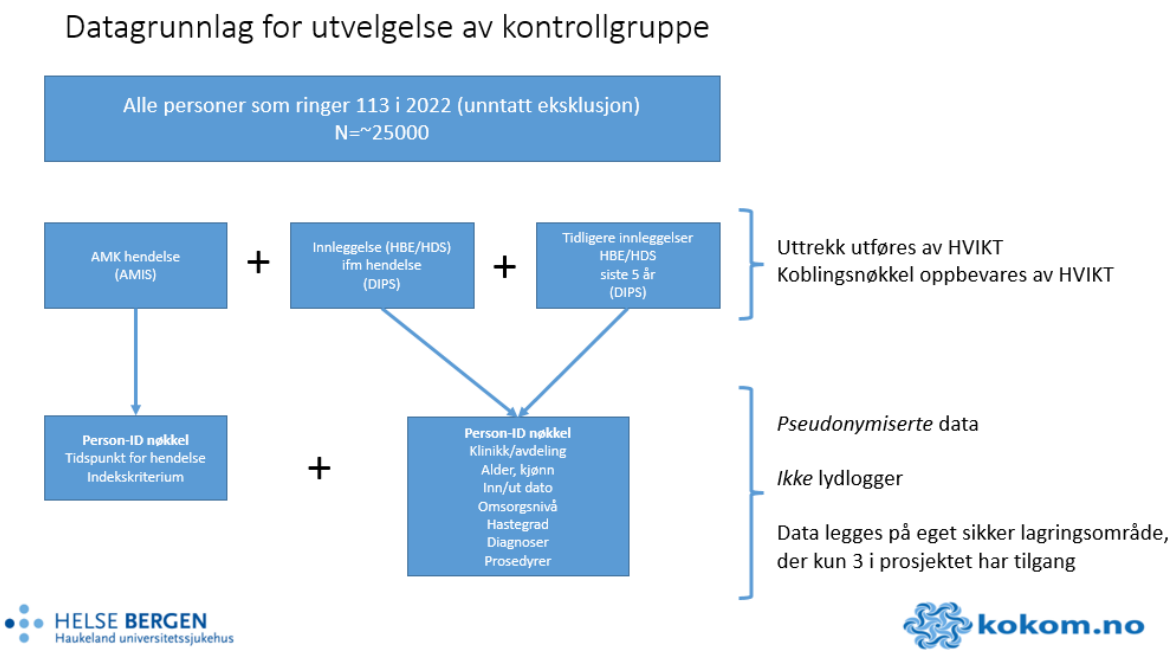
15.12.23: Addendum on data handling in the selection of the control group:

Helse Vest IKT will extract DIPS and AMIS variables (as previously described) for the large control group of approximately 25,000 patients. Helse Vest IKT will store these data securely on a research server. A linkage key will be created and stored by Helse Vest IKT according to guidelines, and the dataset for the approximately 25,000 individuals who called 113 in 2022 will be delivered to the research group without national identity numbers.
All data analysis will be carried out using automated standard tools such as SQL, Python, SPSS, and Excel available within the health trust. Data from the large control group will be analysed in aggregated form to construct a representative subset of 3,000 patients, and will not be reviewed manually at the individual level.
The presentation provided at the committee meeting on 26.10.23 represents the current procedure to be used in selecting control patients. We will therefore not extract or use audio logs for the large group of 25,000.
For the final control group of 3,000 patients, an application will be made to the Health Data Service for prescription data, as previously described, and audio logs will be retrieved. All data will be securely stored on the designated research server assigned by Helse Vest IKT. These 3,000 patients will receive an information letter approved by REK.

REK West summarised the project group's oral presentation on data handling/selection of the control group after the meeting on 26.10.23 as follows:

The researchers explained the steps and data flow used to select a representative control group. The large control group (approx. 25,000) is selected via AMIS (the EMS communication centre's record system) and consists of all patients who contacted AMK in 2022 (except stroke patients and other exclusions described earlier). For this large group, the following data will be collected: time of event and index criterion (AMIS), data from admissions to HBE/HDS in connection with the event (DIPS), and data from previous admissions at HBE/HDS over the past 5 years (DIPS).
DIPS data for this group include clinic/department, age, sex, admission and discharge dates, level of care, urgency, diagnoses, and procedures. Helse Vest IKT performs the extraction and keeps the linkage key. De-identified data are transferred to the researchers, who will not have access to the linkage key. For this large control group, audio logs will not be listened to, registry linkages will not be performed, and journal text will not be used—only structured fields from the electronic medical record. Data from this group will be analysed to create a representative control group of 3,000 participants. For these 3,000 participants, audio logs will be listened to, DIPS data will be used, and linkage with the Prescription Database will be performed. It is planned that an information letter with opt-out rights will be sent to these 3,000 participants.

From the project group's description of the control group data basis presented at the meeting with REK West on 26.10.23:



271124: Addendum regarding prescription data from the Norwegian Prescription Database (Legemiddelregisteret):
Previously, an application was submitted to REK—and approved—to use prescription data from the Norwegian Prescription Database (LMR) for the final control group. It had also been applied for, and processed, that prescription data could be used for stroke patients (2018/2019), but at that time it was assumed that the data source would be the Summary Care Record (Kjernejournal). As Kjernejournal has now been discontinued, and in order to obtain prescription data for the stroke patients equivalent to those for the control group, an

application has today been submitted to REK to approve extraction of prescription data from LMR for these patients.
For the AI development, it is essential that we have the same data available for the stroke patients and the control group, and it is regrettable that we mistakenly believed we already had approval for LMR data for the stroke group. The Health Data Service (HDS) has been informed today, and as soon as REK has processed the amendment submitted today, HDS will be notified.

160925: Extension of project period:
An application is submitted to REK to extend the project period from 31.12.2025 to 31.12.2027. This is due to several factors, including challenges with data extraction for the final phase of the project. Testing of the AI model on all 2024 patients in AMK Bergen is currently delayed, and it is not realistic to complete this work before 31.12.2027 at the earliest.