DELIVERABLE NO. 3.7 – GOOD PRACTICES IDENTIFICATION MANUAL

WP3 Analysis and benchmarking of stroke healthcare pathways

Due date:	31/10/2019
Actual submission date:	30/07/2021
Responsible partner:	IACS
Version:	Version no. 1
Status:	Release
Dissemination level:	CO

Deliverable description:
This deliverable contains the analysis methodology and the comparison of the activities A3.2, A3.3, and A3.4, producing the criteria to identify and select good practices in stroke care among the regions participating in ICTUSnet.

Revision history			
Version	**Date**	**Comments**	**Partner**
1	14/06/2021		IACS
2	29/07/2021		IACS

Authors	
Name	**Partner**
Francisco Estupiñán-Romero	IACS
Javier González	IACS
Natalia Martínez	IACS
Juan González	IACS
Enrique Bernal Delgado	IACS

Contributors	
Name	**Partner**
María Rosa Vivanco	AQuAS
Carlos Tellería Orriols	IACS
Carmen Jiménez	IDISBA
María Herrera	Navarrabiomed
Hugo Filipe Baptista	ARS Norte

Experts

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This deliverable contains the analysis methodology and the comparison of the activities A3.2, A3.3, and A3.4, producing the criteria to identify and select good practices in stroke care among the regions participating in ICTUSnet.

Health care configuration and organization is deeply adapted to the physical and material conditions of the territory and the governance structure of the Health System with differences competencies in the management of the different healthcare and social care resources in each territory, requiring different evaluation approaches focusing in the assessment of different aspects of health care of special interest for each region; thus, hindering the set-up of a common evaluation framework for Stroke care practices that could be directly implemented using the information already available without incurring in higher spending of scarce resources for the purpose of the evaluation only.

ICTUSnet participants agreed on criteria to select good practices mainly based on the results of the empirical assessment of the process of the acute phase stroke care and the focus on the documentation and evaluation of the implementation of any plan, program, strategy, or campaign promoted or developed within the regions tackling primary prevention, stroke awareness, follow-up, and rehabilitation.

Following these criteria the good practice selected corresponded to the regions of Aragón and Navarre, both including most activities considered relevant in the stroke care process in their care pathways consistent with the theoretical model and guidelines recommendations with a focus on timeliness to reperfusion therapies.

1. Introduction

The ICTUSnet project aims to improve the quality of stroke healthcare, including stroke care strategies. The present deliverable belongs to WP3 “analysis and benchmarking of stroke healthcare pathways”, which aims to perform an analysis and comparison of the different regional stroke care models through all the stroke care stages, including the rehabilitation phase. The project involves stroke regional plans of six regions of Spain (Aragon, Balearic Islands, Catalonia, and Navarra), France (Occitanie) and Portugal (Norte). The objective of this deliverable is to describe the criteria and the process used to select the two good practices

The methodology used for this study is based on both quantitative and qualitative

Among the different stroke regional plans that have been analysed, the Aragon Plan of Stroke Care (in Spanish, *Plan de atención al ictus en Aragón*), and the Navarra Stroke Code (in Spanish, *Código Ictus en Navarra*) stand out for their monitoring capacities and the compliance with the care pathways recommended in the literature (i.e. clinical guidelines) in the acute assistance of the stroke episode, and the accuracy in the explanation of the different activities and resources for health promotion, primary prevention programs and the stroke survivors trajectories in the rehabilitation phase. Both practices have been regularly updated and provide the strategic lines and objectives in all the stages of stroke care, including primary prevention, acute care and the rehabilitation process beginning now of the first medical assistance. The Aragon Plan of Stroke Care includes specific information for each phase of the Stroke Care, including activities, key players, criteria, services, and resources. In the Navarra region, stroke rehabilitation is included in the Integrated care strategy for chronic and multi-pathological patients (in Spanish, *Estrategia de atención integrada a pacientes crónicos y pluripatológicos*), developed in 2013. The main rehabilitation highlights of this strategy are to improve the quality of life of chronic and multi-pathological patients and to promote their autonomy. The document focuses on rehabilitation from a high-level perspective, meaning that the information provided avails for several diseases and is not specifically focused on stroke.

Both Aragón and Navarra were able to complete the empirical assessment of their stroke care process through the process discovery methodology checking that their care pathways are compliant with stroke care recommendations, thus deemed as good practices.

Overall, regions were able to participate in the empirical analysis of their stroke care processes rendering a map of the main pathways of stroke care in the subacute phase. However, there are significant differences in the level of detail among the different regions.

2. Methodology

2.1. Designing an evaluation framework for Stroke care practices

A scoping review of academic literature and other relevant documents related to stroke (i.e., clinical guidelines and international consensus on good practices in stroke care) was performed with the goal of stablishing the normative or recommended care pathway for stroke patients and collecting **indicators** used in the evaluation of stroke that could be used later to empirically assess the health care provided for stroke patients by the health system in the different participant regions and identify good practices by comparison of the care process among regions and with the theoretical benchmarks.

Regional plans and programs on healthy lifestyle focusing cardiovascular health and particularly atrial fibrillation and stroke, and stroke awareness campaigns were sort out and mapped for each region focussing on whether they were routinely evaluated on their implementations or by their overall results, compiling main indicators used for the evaluation of those primary prevention plans as part of the evaluation framework.

In the same sense, a scoping review combined with in-depth interviews with Stroke care plan coordinators in each region led to the identification of the follow-up strategy of stroke survivors and the mapping the rehabilitation resources available and the secondary prevention activities organized by the different health systems to improve the quality of life of stroke survivors. A pool of indicators aimed to measure the implementation of such rehabilitation processes in each region was selected and subset from the different strategies as part of the evaluation framework.

Finally, a quantitative approach based on machine-learning from the secondary use of healthcare data was used to assess the acute phase of stroke healthcare assistance using process mining techniques to infer the acute stroke care pathway for each region, compare them among regions and benchmark it with the normative pathway scoped from the literature.

2.2. Good practices selection

Health care configuration and organization is deeply adapted to the physical and material conditions of the territory and the governance structure of the Health System with differences competencies in the management of the different healthcare and social care resources in each territory, requiring different evaluation approaches focusing in the assessment of different aspects of health care of special interest for each region; thus, hindering the set-up of a common evaluation framework for Stroke care practices that could be directly implemented using the information already available without incurring in higher spending of scarce resources for the purpose of the evaluation only.

This reality lead ICTUSnet participants to agree on criteria to select good practices mainly based on the results of the empirical assessment of the process of the acute phase stroke care and the focus on the documentation and evaluation of the implementation of any plan, program, strategy, or campaign promoted or developed within the regions tackling primary prevention, stroke awareness, follow-up, and rehabilitation.

3. Process mining of regional health databases

The concept of process mining is referred to data science (or statistical learning) applied to processes to provide novel insights that can be used to identify and address performance or compliance issues. Process mining turns event data into insights and actions to improve business processes.

It requires event data (activities with an associated timestamp) as input to answer process-related questions. In the ICTUSnet use case, we leverage the availability of healthcare data in regional health information systems to analyse the acute phase of the stroke care from Aragon, Balearic Islands, Catalonia, and Navarre (in Spain) and Norte ARS (in Portugal).

The main aim of the process mining is to produce an empirical model of the processes in place when no formal description of the process can be obtained by other approaches. The empirical process is discovered from the individual-level or case-level data in the first step, named “Process Discovery”.

This empirical process enables conformance checking and performance assessment both by comparison with the expected process and performance or by comparison with an available alternative, such as same process from another region.

4. Case selection for process discovery of acute stroke care

The Stroke care process included in the Aragon Stroke Plan counts with 4 phases and 10 subprocesses that cover the different patient's needs. The **subacute phase** involves all the actions oriented towards patient stabilisation, etiologic diagnosis, secondary prevention, socio-sanitary planification and rehabilitation. Subacute phase goes from first 48/72 hours until hospital discharge, and it is formed by two subprocesses, first of which is the "attention on hospital units".

"Attention on hospital units" begins with the arrival of patients to hospital emergency care units, the etiologic diagnosis, and the hospital admission to a specialised stroke unit. The pathway implies the activation of the "Code Stroke" that aim at reading all specialised resources required for diagnosis and treatment making care continuity easier for patients

Following this a priori knowledge, the case selection for the analysis of the subacute phase healthcare assistance of stroke included all patients reaching emergency care services or admitted to a hospital with a diagnosis of stroke during a year. For consistency purposes, we selected 2017 as first year of study acknowledging the availability of data and the completion of the implementation of the ICD-10th standard in the healthcare information systems of the different regions.

Therefore, a case was selected when:

- There was a Stroke diagnosis at the emergency care services (although we dis no considered diagnosis at emergency care services as confirmed diagnosis unless patient was discharged without admission to hospital)
- There was a main diagnosis of Stroke at hospital admission (we consider this diagnosis to be a confirmed diagnosis of stroke and use it to classify the aetiology of the stroke for further analysis)

Patients were then classified as having an ischaemic stroke, a transient ischaemic stroke or a haemorrhagic stroke depending on their confirmed diagnosis.

Additional information on patients' contact with healthcare services was retrieved independently from where the patients were selected (i.e., based on information from emergency care services or hospital admissions).

5. Federated Analysis Infrastructure

The use individual or case-level data for the process mining analysis set the need to design, develop and implement a solution architecture that enabled both local analyses of the data from each region and the comparative analysis of the resulting processes among regions and with the normative pathway, which lead us to propose a federated analytical infrastructure.

Main characteristics of the federated infrastructure is that each region participating in the analysis acts as a data hub exploiting their own data and analytical capabilities to provide the outputs of their own analysis in a consistent and coordinated manner.

Health Science Institute in Aragón (IACS) acted as coordination hub providing a fully reproducible open-source analytic solution to be deployed and run at each partner within their own premises and systems, thus without any need for data transfer.

This federated infrastructure is private-by-design and secure-by-design there is no data transfer required and the analytical pipeline is provided as a system-independent containerised solution that can be deployed and run in an isolated environment and is fully auditable by the partners.

However, the federated infrastructure required establishing a federated governance including both IT and domain experts from the partners from the different regions, mainly focusing on interoperability issues, both technical and semantic.

Main technical and semantic interoperability issues were resolved by the consensus of the participant partners and materialised in a Common Data Model and an Analytical Pipeline.

6. Common Data Model

The common data model included information on 3 main entities a) Patients, b) Urgent/Emergency care events, and c) Hospital admission events.
The focus was on capturing the maximum number of relevant activities during the subacute phase of stroke care registered routinely in the healthcare information systems of the regions to characterise the process. We finally agreed on up to fourteen (14) relevant activities from reaching the emergency care services to hospital discharge.
Although, we explore the possibility of adding information on outpatient emergency care and emergency transport it was not possible due to inaccessibility or inadequate quality of the data that hinder patient linkage and follow-up with hospital registries.
As time to treatment is a major component of successful reperfusion therapies in ischaemic stroke, we set the timestamps granularity at minutes in the specification of the activity's variables within the common data model.
To capture all cases, both case selection and data model were configured to require looking up immediately previous or past events of the patient withing the health system to look for continuity of care. That mean for a patient complying the selection criteria at hospital admission to look up any emergency care service visits before that admission and vice versa for a patient located at emergency care service look up for any previous or past admission to other emergency care service or hospital, enabling the identification of transfers between hospitals (i.e., from small

hospital to reference hospital and back) or between emergency care services displaying the full organizational configuration of the stroke care in each region.

7. Analytical Pipeline

The ICTUSnet analytical pipeline required from each partner to produce three data files in comma separated value format regarding patient information, urgent care events and hospital admissions, consistent with the expected common data model. Each region IT expert was responsible for producing these inputs through extraction, transformation and load processes from their healthcare information systems or healthcare data bases.
Assistance from IACS IT experts was provided both with the ETL processes and the deployment of the containerised analytical pipeline, although main issues were tackled jointly as they usually implied updates in the software or new developments.
The analytical pipeline was design and developed as an integrated modular solution including a database management system, a process mining module consisting of an Event Log Builder tool and a Process Mining tool and a pre-design HTML report that was produced as output.
The data management system selected for the task was MongoDB, as it allowed the required flexibility to systematically reflect the hierarchical nature of the event logs where activities are nested within their respective timestamps for each case.
The event log builder was developed using Python to ease the management of the required data at scale and implement additional rules for quality and consistency checks.
Finally, the process mining module was developed leveraging the statistical learning and process mining capabilities already implemented in many packages of the R statistical language.
The ICTUSnet analytical pipeline was distributed both as a Docker containing all modules and instructions on how to deploy and execute it in each partners systems and as a Virtual Machine for those partners with operating systems not supporting Docker by default. Both versions of the pipeline were publicly registered and published in Docker Hub and ZENODO, for ease of dissemination and version control.

8. ICTUSnet Analysis Dashboard

The main output of the process mining analysis was defined as an Rmarkdown file producing a stand-alone HTML report containing both code and interactive figures resulting from the process discovery. The ICTUSnet Analysis Dashboard was segmented in different tabs containing insight and figures on the stroke care process a) in general, b) for patients diagnosed of ischaemic stroke and, c) for patients diagnosed of haemorrhagic stroke. All figures and results were the same between the three tabs aiming for consistency in the interpretation, although results differed as expected between the different processes.
The process discovery results were mainly conveyed by three types of figures all characterising the sequence of activities underwent for a patient with a suspicion of stroke after reaching the healthcare services. These figures included a trace explorer, a process map (based on frequency), a process map (based on median times between activities), and a continuity matrix of the activities. All analysis were limited to the 95% of cases studied leaving out the most infrequent pathways of care to reduce the visual clutter produced by irregular or unique paths.

The trace explorer colour-encoded each type of activity characterising each pathway of care within the health system sorted by their relative frequency of patients following each pathway. Only most frequent traces, or commonly known as pathways of care, were plotted although the function producing the trace explorer plot could be parametrised to focus on most infrequent or irregular paths.
The process map or process model are graph-based plots showing the activities registered during the stroke care process as nodes or vertices while showing the transitions or paths between activities as arrows or edges. In this kind of plot, process is visualised as the continuum of activities linked from 'Start' to 'Finish' through the different pathways, as arrows or edges between activities follow the curse of time. Additionally, both nodes and arrows can include further information on the process such as the absolute frequency of patients transitioning between two continuous activities (also encoded by colour density of both nodes and arrows) or the median time in hours taken for those same patients to transition between the activities along the time of analysis. This information characterises the process enabling the identification of key activities and bottlenecks.
Finally, a continuity matrix was added to the report as a quality control on the execution of the process mapping / process discovery exercise showing via heatmap the absolute frequency of activities that led to each other. Asymmetries in this continuity matrix would indicate issues in the timeliness and or sorting mechanism of the activities during the process discovery heuristic along with issues with the activities encoding.
However, a rather simple output, the ICTUSnet Analysis Dashboard achieve discovering the healthcare process for stroke in each region, including the organization of the continuity of care between emergency care services and hospital services, and link care pathways with health outcomes.
Additionally, process maps represented as graphs can be compared both visually and systematically through mathematical analysis rendering the instrument enabling conformance checking and inter-regional comparison.
Outputs from each region (except Occitanie) are published online as part of the deliverables of the project at the ICTUSnet project website.

9. Good Practices selected

The process maps from all regions (except Occitanie) were compared both in terms of the specification of the activities routinely registered in healthcare information systems for patients undergoing a stroke following the case selection criteria for similar timeframes and in terms of the distribution of the time transitioning from one relevant activity to another and for completion of the assistance from reaching the emergency care service to receiving first assistance in case of haemorrhagic strokes, or fibrinolysis in case of ischaemic strokes.
A simple conformance checking was conducted based on the adequate portrayal of the main relevant steps in the stroke care process as reflected in the international consensus and in the regional stroke care plans; although no formal test was applied to the process maps to check for similitudes with a normative or theoretical process as it was deemed highly dependent on the service organization of each region.
The good practices selected based on the results of the empirical assessment of the process of the acute phase stroke care and with a focus on the documentation and evaluation of the

implementation of any plan, program, strategy, or campaign promoted or developed within the regions tackling primary prevention, stroke awareness, follow-up, and rehabilitation were:

9.1. Aragon

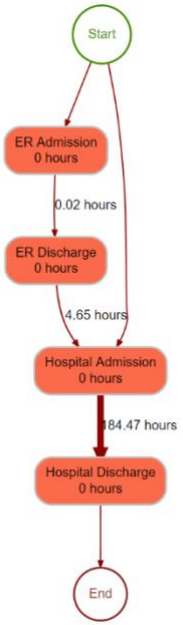
The process mining analysis for Aragon included almost all activities considered relevant in the care of stroke patients comprising from emergency care service arrival to transfer to a long-term care hospital or other facility. The quality of the registries from Aragón also enabled mapping transfer between small to reference hospitals for stroke care with multiple instances in different emergency care services conditioned by the low-density population and the organization of the healthcare results within the window of opportunity to apply reperfusion therapies such as fibrinolysis, or even thrombectomy during the hospital admission.

9.2. Navarre

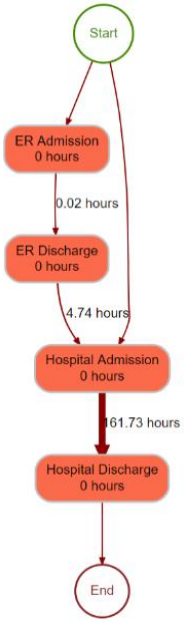
The process mining analysis for Navarra also included main relevant activities with a special focus on image diagnosis both during emergency service visit and hospital episode and reperfusion therapies both fibrinolysis and thrombectomy during hospital admission producing interesting insight on recent organizational changes underwent to improve the stroke care process that had not been assessed yet.

Participants from all regions agreed on the usefulness of the process mining analysis to gain insight and enable healthcare professionals involved in stroke care planning and management to visualise the entanglement of the process thorough the healthcare organization requiring higher coordination between actors providing care at the different stages even during the acute phase with a focus on providing best quality of care and preserve best quality of live for stroke patients.

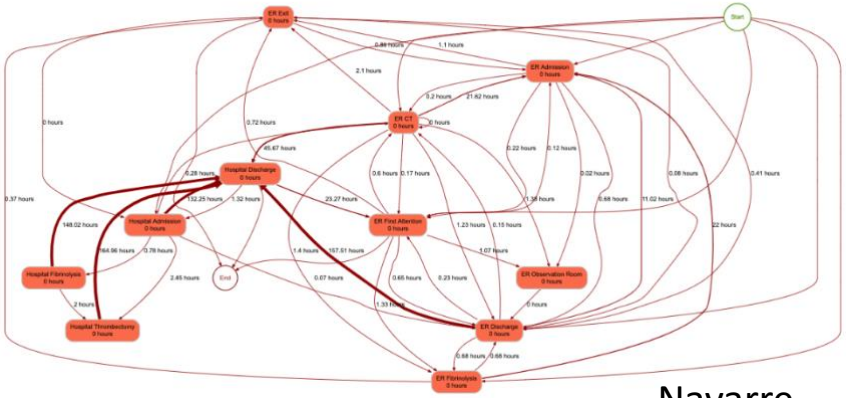
10. Annexes



North Portugal 2019

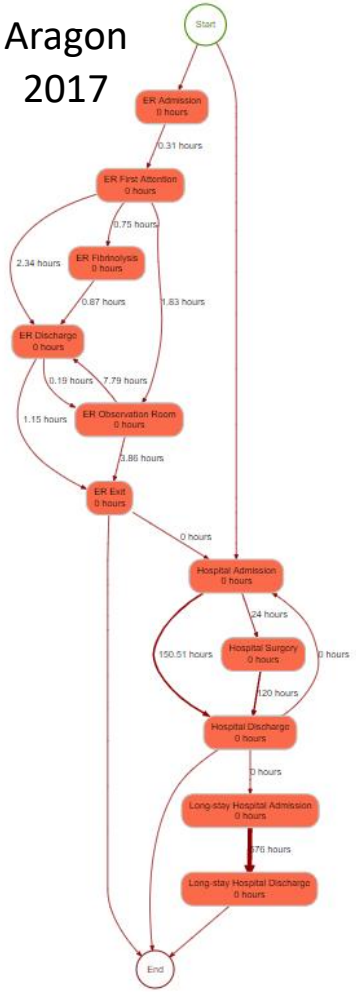


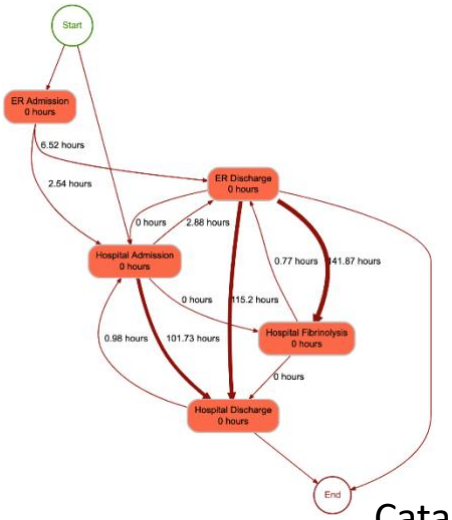
North Portugal 2020



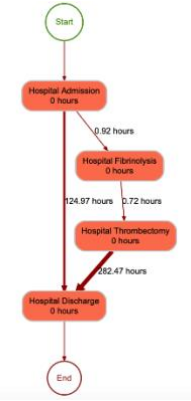
Navarre 2020

Aragon 2017





Catalonia 2017



Balearic Islands 2018