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Original Article

Endovascular Treatment for Stroke in a Single Center in a Developing Country: Permanent Training is the Key

Omar Pichardo,[1,2] Picazo Alan,[1] Chudyk Jorge,[3] Omar Castillon,[2] and Jonathan Zuñiga[1]

Objective: In Mexico, the systematic implementation of mechanical thrombectomy has been delayed due to several factors, such as the conditions of the healthcare system. The objective of this report is to explain the experience in our center going through these circumstances, how we have overcome them, our results, and our pending challenges.

Methods: This is a single-center, independent, and retrospective study of prospectively collected data destined to record consecutive patients treated with endovascular techniques at a Mexican hospital that implemented a mechanical thrombectomy program for large vessel occlusion (LVO). Patient selection began in February 2017 and ended in January 2020. Patients selected were between the ages of 18 and 80, and could be treated within 8 hours after onset of symptoms. The timeline of the analysis was divided in half (i.e., 18 months). We prognosticate that our concept of permanent training could have an impact on clinical outcomes.

Results: In all, 73 patients gathered, of which 60.3% were women and 39.7% were men, with an average patient age of 62 years old. The average Onset-Door time was 248 minutes, and mean Door-Recanalization time was 91.7 minutes, where 29.6% (27.2 min) were used in the endovascular procedure per se. The results obtained were as follows: five (6%) patients with a thrombolysis in cerebral infarction (TICI) <2B and nine patients (12.3%) with a TICI 2B. TICI 2C and 3 were considered optimal results and found in 59 (80.8%) patients. It was found that 17 (23%) patients treated in the first 18 months had favorable outcomes (modified Ranking Scale [mRS] <3), and in the last 18 months, 45 (33%) patients had favorable outcomes ($p = 0.0001$).

Conclusion: Developing countries such as Mexico usually present particular conditions that are not part of the algorithms generated in developed countries. Nevertheless, with logistic adaptation, creativity, and above all, permanent training, similar results to those in other parts of the world can be achieved.

Keywords ▶ LVO, aspiration, stent retriever, training, developing country

[1]*Neurosurgery Department, Hospital Regional 1o de Octubre, ISSSTE, Ciudad de, Mexico*
[2]*Neurosurgery Department, Centro Médico ABC, Ciudad de, Mexico*
[3]*Neuroradiology Department, Hospital Faro del Mayab, Mérida, Yuc., Mexico*

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Corresponding author: Omar Pichardo. Neurosurgery Department, Centro Médico ABC, Cons. 072, Av. Carlos Fernández Graef 154, Santa Fe, Contadero, Cuajimalpa de Morelos, 05330 Ciudad de México, CDMX
Email: omar.pichardo.md@gmail.com

Introduction

Since 2015, when the “five stars” (MR CLEAN, SWIFT PRIME, REVASCAT, EXTEND IA, ESCAPE) were published, treatment for acute ischemic stroke changed drastically all over the world.[1–6] For large vessel occlusion (LVO), the American Heart Association (AHA) guidelines published in 2018 considered mechanical thrombectomy as evidence level A class IA, which is why the comprehensive stroke centers have incorporated it as the first line of treatment along with intravenous thrombolysis.[7]

This modification in Stroke treatment has generated important changes, adaptations, and innovations in the different areas involved.[8)] In this manner, protocols and algorithms have been developed in various parts of the world to make the transferring of patients to a center with endovascular capability faster, under the principle of “time is brain.” This way, Drip and Ship and Mothership models emerged and continue to evolve. Other models such as on-demand endovascular therapy and the Mobile Stroke Unit have also appeared.[9)]

Besides, technology is increasing the possibility of treating more patients with the development of dedicated software and even mobile apps. This allows the communication between the professionals involved, pre-notifications to hospitals, and real-time tracking of patients before they arrive at the emergency room.[10,11)]

However, building similar protocols in developing countries is a different story. The treatment centers present dissimilar conditions; its infrastructure is often inferior to those in developed countries, and the healthcare models are usually deficient.[12)] Despite this, countries such as Colombia, Brazil, and Argentina have reached high standards of treatment.[13)]

Mexico is the 10th most populated country in the world and has over 119 million inhabitants according to the 2015 census and a current population of more than 130 million inhabitants is estimated.[14)] This outlook adds difficulty to the healthcare system of this country since even when it consists of an amalgam of private and public institutions, it does not guarantee health access and quality service for all.[15)]

In Mexico, the implementation of mechanical thrombectomy has been delayed due to all these factors, and the objective of this report is to explain the experience in our center going through these circumstances, how we have overcome them, our results, and our pending challenges.

Materials and Methods

In this retrospective observational study, medical records of all patients undergoing treatment with endovascular techniques at a Mexican hospital that implemented a mechanical thrombectomy for LVO program (stroke program) were reviewed.

The selection began in February 2017 and ended in January 2020 (36 months). The inclusion criteria are described below: Patients between the ages of 18 and 80 years old who were able to undergo an initiation of endovascular treatment within 8 hours after onset and previous functional independence,[16)] who scored 6 points or higher National Institute of Health Stroke Score (NIHSS) with a brain

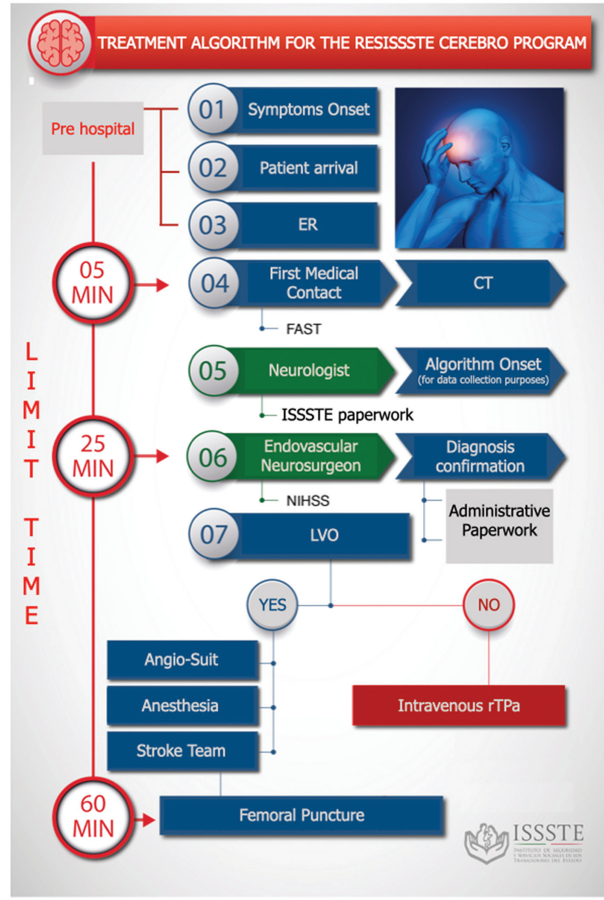

Fig. 1 Stroke Algorithm. The objective of this algorithm was to design a simple tool to use at all times. Multiple situations required the analysis and decision of the stroke team. Adapted from the Algoritmo para el Programa ResISSSTE Cerebro with kind permission from Fausto Macías and Omar Pichardo

computed tomography (CT) equal to or greater than 7 points in the Alberta Stroke Program Early Computed Tomography Score (ASPECTS) scale and LVO confirmed by digital subtraction angiography (DSA). Magnetic resonance was used in none of the cases. In all cases, the request for assessment of our team was considered the beginning of the algorithm (**Fig. 1**) under the suspicion of a patient with a stroke diagnosis. The notification could be sent from the emergency department or any other service or area in the hospital. All patients included were assessed with the NIHSS scale at the beginning, post-treatment, and at 24 and 72 hours after the procedure. The patients transferred to another hospital for any reason, those with uncertain onset, and outside of these criteria were ruled out, as well as those who required additional intracranial angioplasty with a stent to keep the recanalization resulting from thrombectomy.

The diagnosis of the type of stroke was not completed the first 9 months of the data collection period for multiple reasons, mainly due to the unavailability of the heart set of studies (Eco cardiogram and Holter). It was decided to continue with the analysis and not exclude those patients to not reduce our case series, considering that the information was not part of the objectives of this report.

The training and implementation of the algorithm that we developed began in August 2016, and repeated training was carried out for all the personnel involved every 6 months for the following 3 years.

The data obtained included sex, age, ASPECTS, the endovascular device used, thrombolysis in cerebral infarction (TICI) post-procedure (assessed by an external neuroradiologist); NIHSS pre-treatment, post-treatment, 24 hours and 72 hours post-treatment, modified Ranking Scale (mRS) at 90 days; complications (hemorrhage, edema or any condition that required decompressive craniectomy); time of symptoms onset before the beginning of our algorithm and in the curse of it (including first medical contact, neurologist, CT scan, Angio Suite, anesthesia, puncture, and recanalization).

Additionally, we made a chronological review of the cases, analyzing the time used during the execution of our entire algorithm, the time used in the endovascular procedure (Angio Suit), and the mRS obtained at 90 days, to identify if the results improved concerning to the repeated training and the learning curve developed by the entire team involved.

Endovascular treatment

Devices were selected indistinctly by the endovascular neurosurgeon, in most cases, based on the immediate availability of the required materials to carry out the treatment. This way, Solitaire and Solitaire Platinum (Medtronic Inc., Minneapolis, MN, USA) were used as stent retriever, and Sofia (Microvention Inc., Aliso Viejo, CA, USA) and ACE 68 (Penumbra Inc., Alameda, CA, USA) catheters for thromboaspiration, and the combinations between them for the SOLUMBRA Technique.[17)]

Recanalization was considered successful when the TICI was categorized 2C and 3 by an external independent neuroradiologist. The final functional neurological outcome was assessed using the mRS score at 90 days. The favorable outcome was defined as mRS scores of <3.[18)]

Statistical analysis

Distributions of the continuous variables were tested for normality. Continuous variables are presented as mean ± standard deviation (SD) (normal distribution) or as median with its interquartile range (IQR) (skewed distribution). Categorical variables are presented as percentages. We performed bivariate comparisons for baseline characteristics and outcome variables between the stent retriever (STR) and aspiration thrombectomy (AT) groups using the χ^2 test or Fisher's exact test for binary outcomes as appropriate, and Student's t-test (or the Mann–Whitney U test for non-Gaussian distributions) for continuous variables. For all statistical analyses, a two-tailed $p < 0.05$ was considered significant. We analyzed the data with IBM SPSS Statistics Version 23.

Results

The total patients with a suspected diagnosis of stroke were 812, of which 11.7% (n = 95) were eligible for mechanical thrombectomy, and out of them, 14 did not receive treatment for several reasons (coverage, rejected treatment, etc.). 9.9% (n = 81) of the total patients were included in this review and 73 (8.9%) met the specific inclusion criteria. In all, 44 (60.3%) were women and 29 (39.7%) were men with an average age of 62 years old. The mean symptom onset-door time was 248 minutes, and door-recanalization 91.7 minutes (total algorithm time). The median time spent in the Angio Suit was 27.2 min (29.6%). The results obtained were five (6.9%) patients with a TICI <2B and nine patients (12.3%) with a TICI 2B. TICI 2C and 3 were considered optimal results and found in 59 (80.8%) patients.

Stent retriever was used in 26 (35.6%) patients and aspiration in 34 (46.6%). The combined technique of stent retriever and aspiration was used in 13 (17.8%) cases. The ASPECTS score average was 8. Intravenous tissue plasminogen activator (tPA) was used in 28 (38.4%) patients. General anesthesia was preferred in agitated patients with suspicion of aspiration or vomiting and was administered to 34 (46.6%) patients. Conscious sedation was administered to 39 (53.4%) patients. There was no significant difference in the time used in the recanalization

Table 1 Localization of vessel occlusions and thrombolysis

Occlusion location n (%)	Right	Left
ICA	–	3 (4.1)
M1	21 (28.8)	31 (42.5)
M2, M3	3 (4.1)	6 (8.2)
VB	1 (1.4)	3 (4.1)
Others	2 (2.7)	3 (4.1)
IV tPa	12 (17%)	15 (21%)

ICA: internal carotid artery; IV tPa: intravenous thrombolysis tissue plasminogen activator; VB: vertebrobasilar artery

Table 2 Database by endovascular device: outcome, NIHSS, complications, recanalization time, and ASPECTS

Outcome	All	STR	Aspiration	SRT + Aspiration	*p*
TICI, n (%)	73 (100)	26 (35.6)	34 (46.6)	13 (17.8)	0.766
Grade <2b	5 (6.8)	2 (2.7)	1 (1.4)	2 (2.7)	
Grade 2b	9 (12.3)	5 (6.8)	1 (1.4)	3 (4.1)	
Grade 2c	16 (21.9)	10 (13.7)	1 (1.4)	5 (6.8)	
Grade 3	43 (58.9)	9 (12.3)	31 (42.5)	3 (4.1)	
NIHSS, (IQR)					
24 hrs		9 (9)	4 (6)	9 (8)	0.084
72 hrs		8 (8)	3 (5)	7 (8)	0.108
Complication n (%)		2 (7.7)	1 (2.9)	2 (15.4)	0.357
Recan time n (%)		29 (9.6)	26.8 (8.5)	28.2 (9.3)	0.250
ASPECTS n (%)					0.678
7		8 (30.8)	10 (29.4)	3 (23.1)	
8		6 (23.1)	13 (38.2)	4 (30.8)	
9		5 (19.2)	4 (11.8)	2 (15.4)	
10		7 (26.9)	7 (20.6)	4 (30.8)	

ASPECTS: Alberta Stroke Program Early Computed Tomography Score; IQR: interquartile range; NIHSS: National Institute of Health Stroke Score; Recan time: recanalization time (time spent in the Angio Suit); TICI: thrombolysis in cerebral infarction

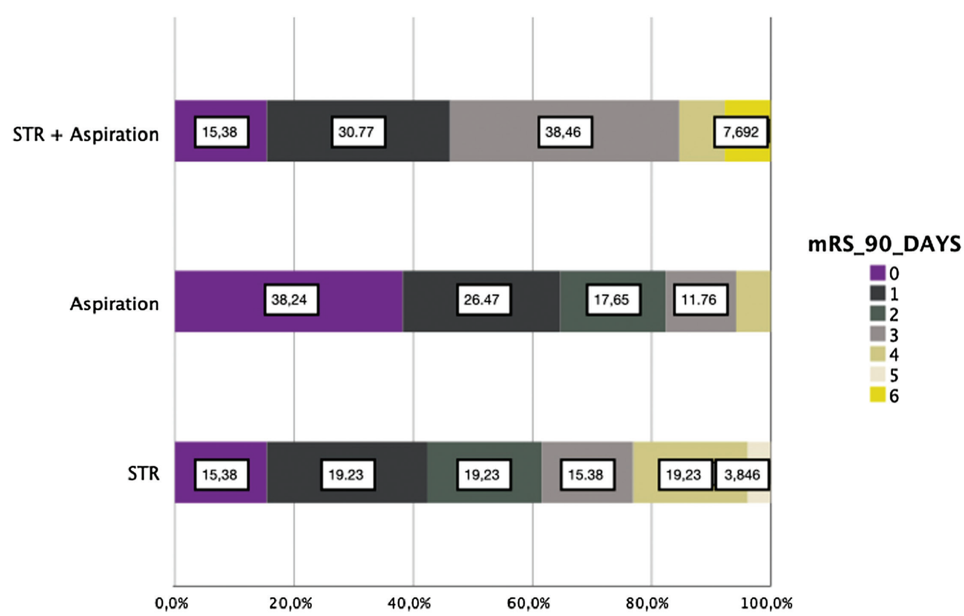

Fig. 2 Outcome by Endovascular device. STR: Stent Retriever; SRT + Aspiration: Solumbra

with any of the two options ($p = 0.203$). The most common location of occlusion was the proximal segment of the left middle cerebral artery (MCA; M1) (45.2%); 35.6% was in the same topography of the right MCA, and 5.5% were cases of the posterior circulation. The rest of the cases were spread among all the other topographies (**Table 1**). Complications occurred in five (6.8%) cases, and all these patients needed decompressive craniotomy.

Different approaches were used to perform this analysis (**Table 2**); three groups (according to endovascular devices used) were made and analyzed the total time (symptom onset + algorithm time) and its correlation with the NIHSS at 24 and 72 hours, mRS at 90 days, and ASPECTS scale, finding no statistical significance (**Fig. 2**). The recanalization time was analyzed as an independent factor regarding its correlation with the NIHSS at 24 and 72 hours, and mRS at 90 days finding statistical significance ($p = 0.027$).

Regarding the chronological analysis, 36 months was the length of total data collection, which was grouped into periods of 6 months each. These groups were compared with each other, taking the 90-day mRS, the total time used

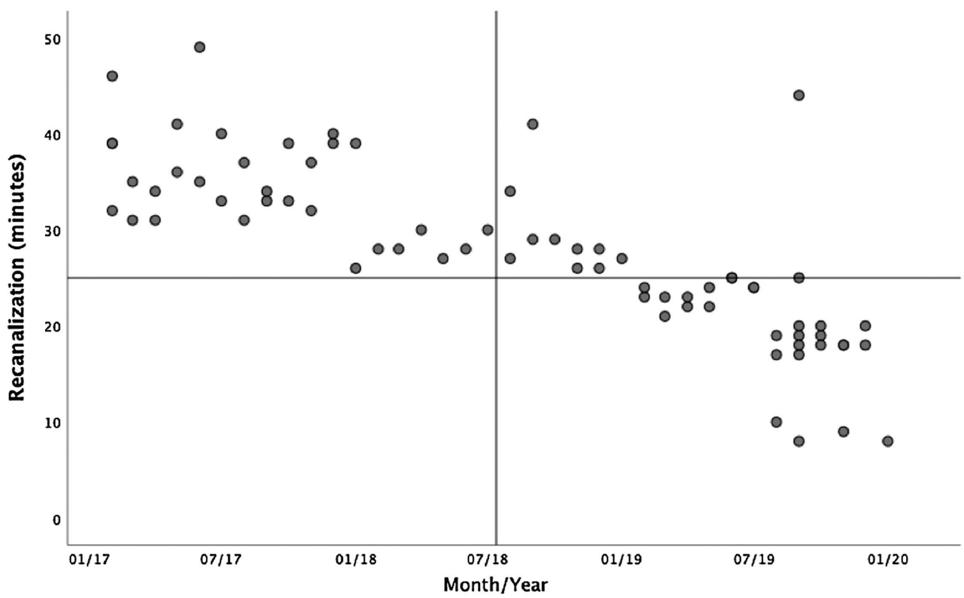

Fig. 3 Chronological case distribution by recanalization time

Fig. 4 Mexico's Health System divided by Public and Private Systems. There is some population that has double coverage and population that has no social coverage at all

in the algorithm, and the recanalization time as variables. The recanalization time (**Fig. 3**) had statistical significance with its decrease in the last 18 months ($p = 0.035$). The temporal midline was set at month 18 (July 2018). During the first 18 months, 17 (23%) patients had favorable outcomes (mRS <3), whereas in the last 18 months (second half), 45 (33%) patients with good clinical outcomes (mRS <3) were found ($p = 0.0001$).

Discussion

One of the main challenges in stroke care worldwide is time, considering that the neuronal loss per minute of ischemia is close to 2 million. Furthermore, premature brain aging has also been associated with a lack of cerebral circulation.[19] This has implied an important logistical deployment in stroke centers all over the world from the beginning of the intravenous thrombolysis. The stroke teams have managed to be very efficient in first-world hospitals, adapting to the changes presented from the commencement, and incorporating new technologies that allow immediate symptom identification, transport, and therapeutic solutions. The Mexican Stroke care system, as well as many others in the Latin American region, has important gaps compared to stroke centers in the developed world. There are two main differences: coverage and fragmentation. The Mexican health

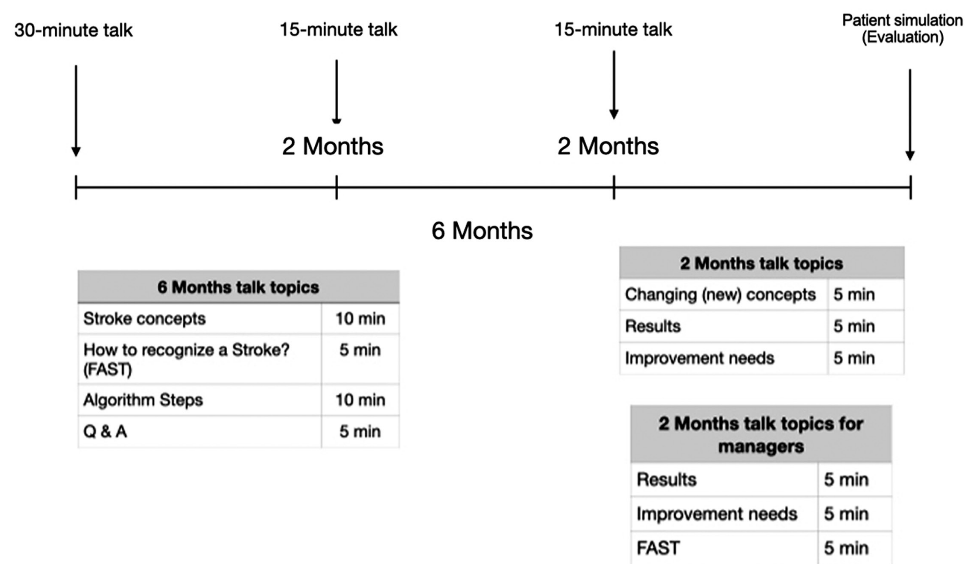

Fig. 5 Training program for 6 months

system is divided into two large groups: private and public. However, even adding both public and private health systems together, universal coverage to the Mexican population is not achieved, reaching less than 60% of the population; self-employed and unemployed people (35%) have access to minimal or no healthcare coverage, and those who pay for private health insurance represent <15%.[20–22] As described in **Fig. 4**, the public system is divided into five large groups, with multiple subdivisions, which operate autonomously with their federal budgets and without total operating dependency on the ministry of health. Therefore, the population must attend the corresponding hospital according to the registered address and the specific medical coverage. That means that any emergency service required should be transferred to the corresponding hospital and not to the nearest one, often resulting in more than 1 hour spent in traffic. According to our experience, this time is closer to 2 hours or 2.5 hours, even when using an ambulance. Moreover, if the patient went to a hospital due to geographical proximity, they could be rejected and transferred for care to the corresponding hospital, regardless of whether it belongs to the same health coverage. Our program focused on patients who spontaneously arrived at the emergency room of our hospital or were previously hospitalized in our facilities for any reason. The present study was carried out in a single center located in northern Mexico City member of the ISSSTE system (Public system).

Our team developed a very easy-to-follow algorithm previously mentioned, which was printed and placed in the emergency room, hemodynamics, and radiology (CT Scan) areas. All hospital staff was trained: managers, primary care physicians, emergency physicians, nurses, security guards, residents, etc. It was a 3-month training period; simulations were made in different schedules and scenarios afterward, adjusting the protocol and correcting the errors identified. After completing 6 months of this process, the stroke program was formally started. The retrospective data collection of this study began 1 month later. Continuous capacitation was a priority from the start, so we repeated the training sessions to the entire team involved every 6 months (**Fig. 5**). We named our program *Hold on Brain**, including the name of our insurance system (*ISSSTE)*. (*Translating note: the program's name in Spanish is *ResISSSTE Cerebro*. The word *ResISSSTE* is formed by the Spanish verb *resiste,* which means hold on in English, and the acronym *ISSSTE.)*

The results obtained in the analysis of this study point to the fact that permanent training was a determining factor for the best outcomes of patients, mainly by reducing the minutes used in each step of the algorithm, which triggers more immediate attention. As mentioned before, **Fig. 3** shows the notable downward trend in the time used in the total of the algorithm. Therefore, a direct correlation can be detected between the chronology of the case and the mRS obtained at 90 days (**Fig. 6**).

These results can be attributed to the learning curve expected in any new process but also to the training plan developed and commented in this report. It was reviewed

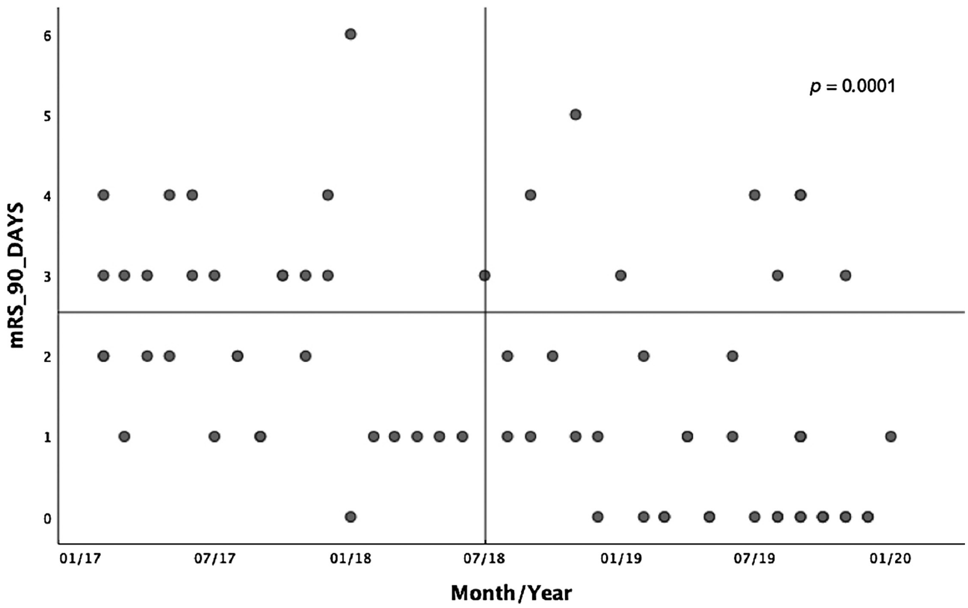

Fig. 6 Chronological Case Distribution by Outcome (mRS). The line on the "Y"-axis limits the good outcome (>3) and the line on the "X"-axis the middle timeline. mRS: modified Rankin Scale

which points of the algorithm had a reduction in the minutes used, finding that enabling the Angio-suit and in the initiation of anesthesia had 9.9% and 13.8%, respectively (p = 0.025). These two steps cannot be improved with the learning curve because it depends specifically on the motivation to do it, and not on how many times one does the same tasks. The so-called *permanent training* becomes relevant considering that our team has long-term elements and temporal elements. The long-term elements are our group of residents (one assigned to the stroke team for 3 months) and two endovascular neurosurgeons. The rest of the team (anesthesiologist and two nurses and X-ray technician) are assigned weekly, rotating every 2 weeks.

These training elements are broken down in **Fig. 6**. After 18 months, we suspended the 15 minutes talks and only continued with the coaching every 6 months to all staff. In this scenario, training non-medical personnel (such as managers) was essential, since even without clinical evaluations, for the reasons explained above, they can stop or delay the care of a patient with stroke. In this way, permanent training modified the institution's protocols to generate more immediate attention.

For the recanalization, the device selected by the endovascular neurosurgeon was used indistinctly. In case three attempts with any of the two techniques that did not achieve a TICI >2B were made individually, another device was added. A total number of 13 patients who required the combined technique. Turk A and cols reported not finding any differences in the time used and the TICI obtained between the treatment with stent retriever and aspiration,[23,24] our results showed the same trend. The TICI 2C and 3 reports were associated with a lower NIHSS at 24 hours and an mRS <3 at 90 days. Our TICI data could be slightly higher than some other reports; however, this did not show any outcome (mRS) difference at 90 days compared to other studies.[25]

Our immediate challenges point directly to the reorganization of the national infrastructure to organize stroke centers geographically, regardless of medical coverage. This paper was written in the context of the Covid-19 pandemic, which made many robust health systems in the world collapse. In Mexico, the division of the health system generated a slow and unstructured response to the crisis. All these differences between health systems showed the importance of adapting international protocols to the realities of developing countries as quickly as possible.

We believe that the scope of this report beyond the findings reported will serve as an incentive for colleagues in other latitudes with similar circumstances to ours. This way they can continue to promote stroke centers around the world, incorporating current technological elements and thinking about those to come in the future.

Conclusions

Endovascular procedures for LVO dramatically changed the course of the disease since 2015 and its management has continued to evolve since then. However, developing countries such as Mexico usually present particular conditions that are not part of the algorithms generated in developed countries. Nevertheless, with logistic adaptation, creativity, but above all, permanent training, similar results to those in other parts of the world can be achieved.

Disclosure Statement

The authors declare that they have no conflict of interest.

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