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The use of a smartphone application to improve stroke code workflow metrics: A pilot study in a comprehensive stroke centre

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Abstract

Background: Timely coordination between stroke team members is of relevance for stroke code management. We explore the feasibility and potential utility of a smartphone application for clinical and neuroimaging data sharing for improving workflow metrics of stroke code pathways, and professionals' opinions about its use.

Methods: We performed an observational pilot study including stroke code activations at La Paz University Hospital in Madrid, from June 2019 to March 2020. Patients were classified according to the activation or not of the JOIN app by the attending physician. Clinical data and time-to-procedures were retrieved from the app or from the hospital records and the Madrid regional stroke registry as appropriate and compared between both groups. An anonymous survey collected professionals' opinions about the app and its use.

Results: A total of 282 stroke code activations were registered. The JOIN app was activated in 111 (39%) cases. They had a significant reduction in imaging-to-thrombolysis (31 vs 20 min, $p = .026$) and in door-to-thrombolysis times (51 vs 36 min, $p = .004$), with more patients achieving a door-to-needle time below 45 min (68.8% vs 37.8%, $p = .016$). About 50% of the users found the app useful for facilitating the diagnosis and decision-making; interoperability with clinical files was considered an opportunity for improvement.

Conclusions: This pilot study suggests that JOIN helps improve and document workflow metrics in acute stroke management in a comprehensive stroke centre. These results support testing JOIN in a prospective randomised study to confirm its usefulness and the general applicability of the results.

Keywords

Healthcare services, stroke code, mobile apps, mobile health, telemedicine, telestroke, thrombolysis

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Introduction

Stroke is one of the leading causes of death and disability worldwide. It is considered a time-dependent emergency in which rapid diagnosis and treatment increase the probability of a good outcome.[1] Therefore, there is a need for optimal coordination among all stakeholders involved in acute stroke management to expedite workflows and ensure that the patient reaches an accurate diagnosis and adequate treatment in the shortest time possible.

There is a continuous effort to improve stroke management timeliness and reduce onset-to-treatment time, particularly in regard to reperfusion therapies.[2] Several recently developed smartphone applications have enabled seamless information sharing between medical teams, which could improve stroke code workflows. These applications have shown reliability for evaluating stroke severity,[3] high accuracy in neuroimaging diagnosis,[4,5] feasibility of implementation and improvement of coordination among team members,[6] as well as the potential to reduce time metrics and increase the rate of reperfusion therapies.[7,8] However, the majority of these apps have not been widely implemented in health systems, one possible reason being a lack of physician engagement in new management protocols. Therefore, it is important to consider the opinion of clinicians when implementing these new tools.

Our aims were (a) to explore the feasibility and potential utility of a smartphone application for recording and improving workflow metrics in stroke code management in a comprehensive stroke centre and (b) to evaluate how the app's users perceived its addition to their usual work protocols, prior to the development of a larger trial of the app.

Methods

This was an observational feasibility pilot study including all stroke code activations at La Paz University Hospital in Madrid, from June 2019 when the use of the JOIN smartphone app was implemented to March 2020 when the first peak of the COVID-19 pandemic forced us to modify the customary stroke code practices.[9]

JOIN app

The JOIN mobile app was used throughout the study. JOIN is certified as a medical device (CE Class I) aimed at speeding clinical communication. JOIN provides mobile access to hospital information technology systems and uses a patented streaming technology to stream big data sets, enabling healthcare professionals to share real-time information quickly while fulfilling all security standards. To safeguard the patients' clinical information, JOIN uses advanced encryption methods and data anonymisation techniques, and it customises anonymisation rules for each facility. It is European Union General Data Protection Regulation and ISO27001-compliant and United States Food and Drug Administration-certified. In addition to traditional messenger functions such as chat, voice and video telephony, JOIN offers dedicated medical features, such as an integrated DICOM viewer, timestamps, patient cases and other functions to optimise medical workflows. It allows the user to record the patient's arrival to the treating hospital and to collect relevant clinical information (sex, age, National Institute of Health Stroke Scale (NIHSS) score on admission, among others) throughout the stroke code management process. It also allows automatic time-stamping of critical events to track the process: date and time of symptom onset, arrival at hospital, neuroimaging performance, beginning of intravenous thrombolysis (IVT), entering the angio-suite, groin puncture for mechanical thrombectomy (MT) and achievement of recanalization (Figure 1).

Stroke code management

The stroke code management team in our centre is composed of 3 on-site neurologists (1 consultant and 2 residents), 1 on-site neuroradiologist and 2 on-call interventional neuroradiologists outside the hospital. On certain days there is an additional consultant neurologist on duty until 10 pm. IVT and MT for ischaemic stroke are available on a 24/7 basis. The hospital protocols for acute stroke management follow current guidelines.[10–12] All the team members have a smartphone for on-call communication. The stroke code is activated by the Emergency Medical Services (EMS) after attending the patient on-site by calling the neurologists on duty, so that the stroke team can be ready to receive the patient at the Emergency Department (ED) and start the management protocol without the need for a triage on arrival. Therefore, the arrival time is the time the patient arrives at hospital and is received by the neurologist on duty. The neurologists are responsible for recording all clinical data and key management times in the clinical records and overseeing all procedures and actions between the team members.

Both stroke neurologists and trained general neurologists can be involved in on-call stroke code management. All the physicians involved in stroke code management were informed of the availability of the application and were taught how to use it in specific training sessions. There were no criteria nor restrictions for the use of JOIN, which was activated at the discretion of the on-call neurologists by registering the patient upon activation of the stroke code by the EMS. The use of the app was anonymous.

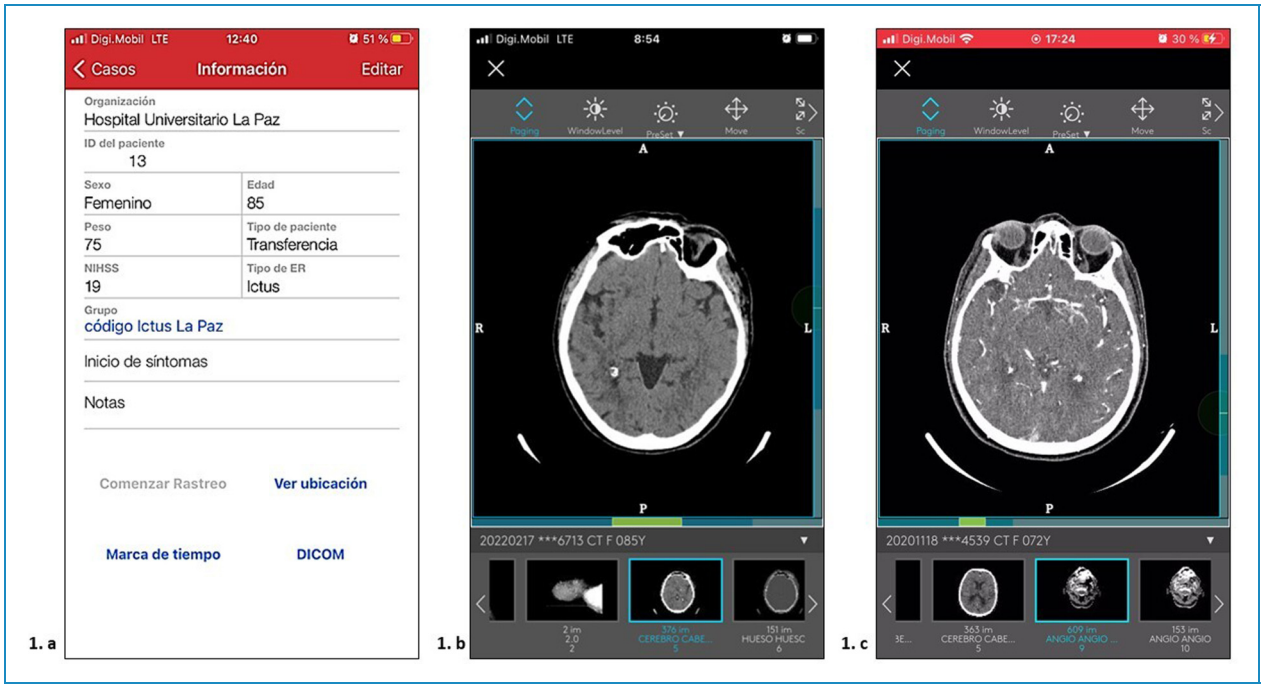

Figure 1. Screenshots of the app. (a) Main screen with patient data and links to the timestamps and DICOM images; (b) A cranial CT Scan view; (c) A cranial CT angiogram view.

Study variables

The clinical data of all the patients for whom the stroke code was activated were retrieved from the hospital records and the Community of Madrid regional stroke registry. We collected demographic data; stroke subtype (transient ischaemic attack, ischaemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage and stroke mimics); blood pressure and glycaemia on admission; stroke severity according to NIHSS score on admission; and revascularisation treatment received, if any: IVT, MT or combined treatment (IVT + MT). Management protocols include recording key management times in the clinical records by the stroke team. For all the patients, we recorded the date and time of symptom onset (if witnessed) or last time observed asymptomatic (if the exact time of symptom onset was unknown); date and time of hospital arrival; and the following time points: door-to-computed tomography (CT) imaging, CT-to-needle, and door-to-needle if IVT, CT-to-groin puncture, door-to-groin puncture and door-to-recanalisation if MT, when applicable. Additionally, stroke team members were encouraged to time-stamp all key time-points in JOIN. For all recruited patients with an in-hospital arrival time that was recorded during the study period, we considered whether the JOIN arrival timestamp was activated to classify the patients as JOIN activated or not JOIN activated. When the app was used, the key time-points were retrieved from the app and compared with those from the clinical records of not JOIN activated patients. If any time-point was missing, either in the clinical records or in the app, the corresponding management time was not calculated.

To assess the subjective value of the app for daily clinical practice, we solicited the opinions of the physicians (neurologists, neuroradiologists and residents in neurology) who were using the app by an anonymous survey. The questions included in the survey are shown in Figure 1. We also asked whether the users would recommend the use of the app to their colleagues. Options ranged from 10 (‘absolutely’) to 1 (‘never’). The users were also asked to include comments at the end of the survey.

Statistical analysis

The descriptive and comparative analyses were conducted considering the predefined groups (JOIN activation vs no JOIN activation). For comparisons of times to CT, the entire sample was considered. For the comparison of times to IVT and MT, only patients with ischaemic stroke were considered. Continuous variables were expressed as mean and standard deviation or median and interquartile range, and compared with Student’s t-test or the Mann–Whitney U-test when appropriate. Categorical variables were described as percentages, and proportions between groups were compared using Pearson’s chi-squared test To assess the effect of the JOIN app activation on the workflow metrics (Door-to-CT, CT-to-IVT, Door-to-IVT, CT-to-MT and Door-to MT) we performed a linear logistic regression analysis. We fit multivariate models to adjust for

Table 1. Clinical characteristics of the study patients.

	Total N = 282	No JOIN N = 171	JOIN N = 111	p value
Demographic data				
Male, N (%)	155 (55)	106 (68.4)	49 (31.6)	.009
Age, mean (SD)	71 (16.2)	70.5 (16.6)	75 (13.9)	.003
Stroke subtype				
Cerebral infarction, N (%)	204 (72.3)	129 (75.4)	75 (67.6)	
Transient ischaemic attack, N (%)	10 (3.5)	8 (4.7)	2 (1.8)	<.001
Cerebral haemorrhage, N (%)	39 (13.8)	30 (17.5)	9 (8.1)	
Stroke mimic, N (%)	19 (6.7)	4 (2.3)	15 (13.5)	
NIHSS score median (IQR)	7 (3–16)	6 (3–16)	9 (3–17)	.292
SBP mean (SD)	162 (29)	162 (29)	162 (28)	.929
DBP mean (SD)	90 (16)	90 (16)	89 (17)	.564
Glycaemia (mg/dL), mean (SD)	126 (40)	123 (36)	134 (45)	.041
IVT, N (%)	73 (26)	37 (21.6)	36 (32.4)	.043
MT, N (%)	76 (27)	43 (25.1)	33 (29.7)	.397
IVT + MT, N (%)	28 (9.9)	10 (5.8)	18 (16.2)	.004

Note. There were 10 patients for whom the stroke subtype was not recorded, all in the JOIN group. NIHSS: National Institutes of Health Stroke Scale; SBP: systolic blood pressure; DBP: diastolic blood pressure; IVT: intravenous thrombolysis; MT: mechanical thrombectomy.

covariables, including those with significant differences in the univariate comparison and those considered clinically relevant; that is, NIHSS score on admission. A p-value <.05 was considered significant for all tests. The statistical analysis was performed using IBM SPSS Statistics V.20.

The data that support the findings of this study are available from the corresponding author upon reasonable request.

This study was approved by the Ethics Committee of La Paz University Hospital (PI-3475). Informed consent was waived as the study was intended to evaluate clinical management aspects and not patient-related data.

Results

There were 282 stroke code activations during the study period, 111 (39%) JOIN activated and 171 (61%) not JOIN activated. Characteristics of the cohort are shown in Table 1.

There was a lower proportion of men, higher glycaemia on admission and a higher proportion of stroke mimics among the JOIN-activated group. There were also more IVT treatments and IVT treatments with mechanical thrombectomy in the JOIN group.

Not all patients had data recorded for every key management time; thus, only patients with data available were considered for calculation of time-to-procedures. These are summarised in Table 2. We found no differences in the time from arrival to CT performance according to JOIN activation. Regarding reperfusion therapies, there was a significant reduction in the CT-to-needle and door-to-needle times for IVT-treated patients managed with JOIN compared with patients for whom JOIN was not activated. Moreover, more patients managed with JOIN activation were treated more quickly than the standard of 45 min from door-to-needle (77% vs 38%, p = .006). However, we did not find significant differences in procedural times for MT, although a tendency to shorter CT-to-groin puncture and door-to-groin puncture times was observed in the JOIN activated patients (Table 2, Figure 2).

Table 2. Comparisons between patients with and without JOIN activation in time-to-key procedures.

CT	No JOIN N = 148	JOIN N = 88	p
Door-to-CT (min) Median (IQR)	21.5 (15–31.5)	20 (15–27)	.144
IVT	**No Join N = 37**	**Join N = 22**	
CT-to-needle (min) Median (IQR)	31.5 (15.5–46.5)	20 (12–25)	.042
Door-to-needle (min) Median (IQR)	51 (37–65)	36 (30–43)	.035
MT	**No Join N = 40**	**Join N = 25**	
CT-to-groin puncture (min) Median (IQR)	90 (52–122)	77 (60–96)	.415
Door-to-groin puncture (min) Median (IQR)	91 (60–118.5)	84 (66–113)	.83
Door-to-recanalization (min) Median (IQR)	146.5 (115.5–206)	141 (103–173)	.339

CT: computed tomography; IVT: intravenous thrombolysis; IQR: interquartile range; MT: mechanical thrombectomy.

The linear regression model showed that the use of JOIN was associated with 17 min reduction in the CT-to-needle and door-to-needle times for the IVT-treated patients, after adjustment for age and NIHSS on admission (Table 3).

Satisfaction survey

The survey was completed by 22 physicians from both the neurology and neuroradiology departments of La Paz University Hospital. The results are summarised in Figure 3. According to our survey, 59% considered that the clinical information collected in the JOIN app should be transferred and recorded automatically in the patient's medical history, 36% found the app easy to use, 50% thought that it facilitates image visualisation and helps in diagnosis and decision making. However, 81% considered that the use of the app added extra work to the usual protocols.

Seven (32%) participants would recommend the use of the app to their colleagues, 5 (23%) were neutral and 10 (45%) would not recommend it. The main reason given for not recommending the app was the consideration that it results in extra work to collect clinical data that also needs to be recorded in the clinical records.

Discussion

We present the results of the implementation of a smartphone application as an additional tool to aid in stroke code management in a comprehensive stroke centre.

We found that the use of the app was feasible and was associated with shorter times to key procedures such as CT-to-IVT and door-to-IVT, with a tendency to a reduction in door-to-MT and door-to-CT times. Also, JOIN activation was associated with a larger proportion of patients treated with IVT within the standard of less than 45 min from hospital arrival.[13] This result is in agreement with previous studies showing better workflow metrics in stroke code management with shorter delays to reperfusion therapies using mobile smartphone applications as a communication tool, and particularly the usefulness of JOIN in this regard.[7,8,14–17] These data support the hypothesis that having an effective tool for real-time sharing of clinical information and images among team members aids in streamlining processes in stroke code management. They also suggest that monitoring the execution helps to speed workflows, avoid unnecessary delays and follow recommended standards.

To shorten the time until the application of specific treatments is of key importance to achieving good outcomes, given the high time sensitivity of acute stroke. Although this concept is fully integrated into the stroke team's protocols, there are several circumstances in clinical practice that can delay the various steps in the workflows; thus, any initiative aimed to improve performance, such as mobile tools to facilitate rapid communication between team members, more rapid and accurate recording of key management times, and easier access to diagnostic images, can be of great help. Our results support this statement.

However, to ensure the maximum performance when implementing a new tool within a given organisation, user involvement and satisfaction are also essential. One of the possible barriers to the implementation of new strategies in hospitals is the staff-reported shortage of time and

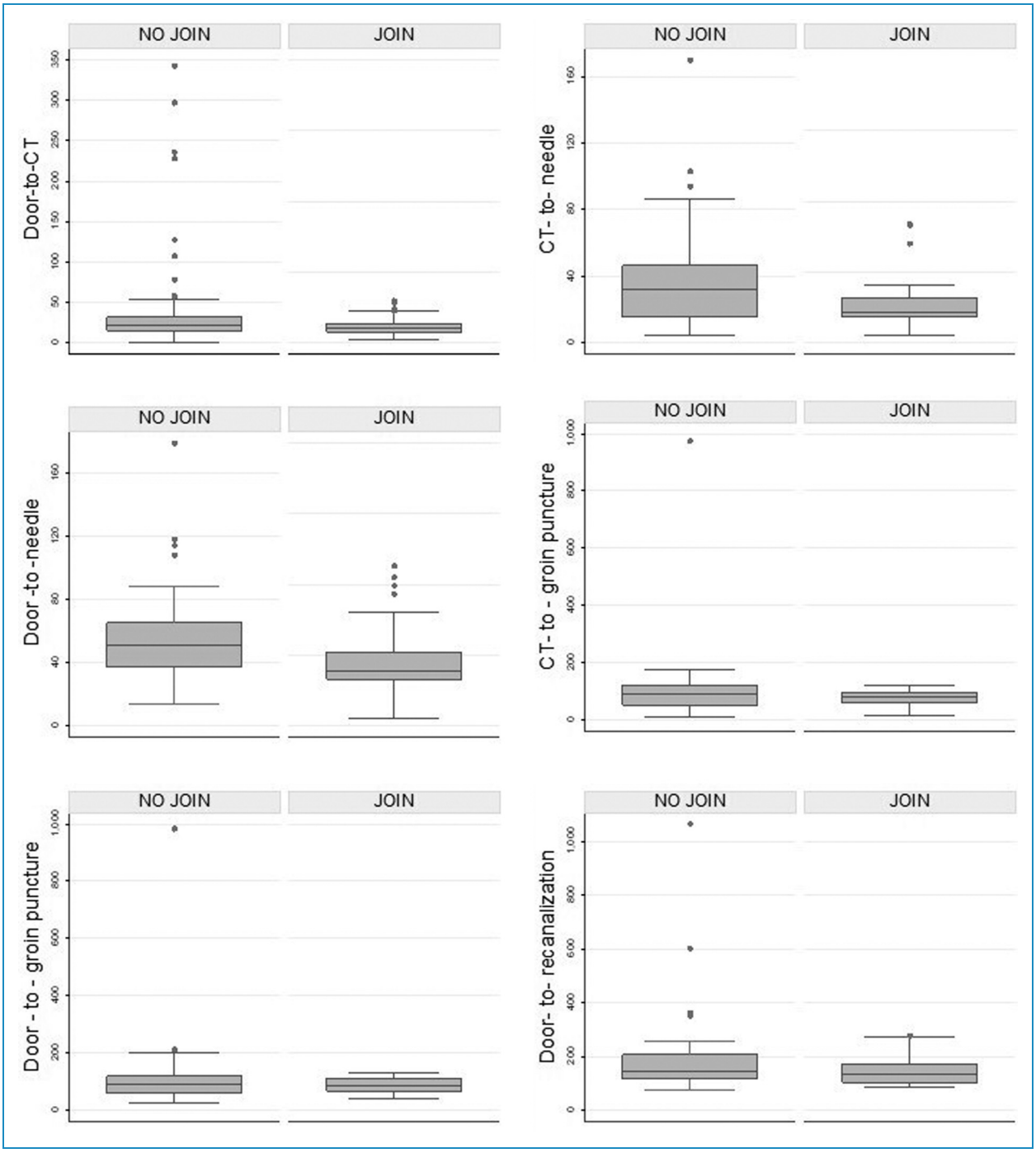

Figure 2. Box plots represent the time to key procedures in both study groups. The *y*-axis shows the time in minutes.

resources available, or the lack of engagement of physicians in new management protocols.[18] For these reasons, we considered the opinion of the clinicians involved from the beginning of the pilot phase of this strategy. The previously reported users' opinion about the use of mobile apps is favourable overall.[19] In our environment, despite the data in favour of using the JOIN app, the results of the opinion survey varied considerably. Many responders had a neutral opinion; only about one-third considered the app easy to use, useful as a communication tool and helpful to speed up workflows; and 50% considered that the app facilitated imaging visualisation diagnosis and decision making. However, JOIN was used only for 39% of the stroke code activations during the study period. When implementing the application within our hospital, we had planned a longer trial period that should have allowed

Table 3. Linear regression models to analyse the effect of JOIN activation on CT-to-thrombolysis and arrival-to-thrombolysis times.

	Coefficient	(95% CI)	p
CT-to-needle time			
JOIN activation	−17.560	−33.836 to − 1.285	.035
Age	0.0468	−0.4360 to 0.530	.847
NIHSS	−0.0070	−0.8808 to 0.8670	.987
Constant	35.624	−0.1458 to 71.395	.051
Door-to-needle time			
JOIN activation	−17.590	−33.566 to − 1.614	.032
Age	0.2085	−0.2630 to 0.680	.379
NIHSS	−0.0647	−0.9247 to 0.7952	.881
Constant	42.840	8.1363 to 77.5445	.016

users to overcome the effect of the initial phases of the learning curve and promote familiarisation with the app to ensure a higher degree of compliance and the recruitment of a larger sample size. However, the COVID-19 pandemic forced us to interrupt the study earlier than expected, which could account in part for the results observed in the use of the application and user satisfaction. Most of the users found the app added extra work to their usual duties, considering that the information collected in JOIN also had to be entered in the patient's clinical records. Interoperability between the mobile app and the patient's files would help reduce the stroke team's work overload, which could lead to an improvement in the perception of the app's usefulness and to encourage its use and its recommendation. The inclusion of the user's feedback about the app in this pilot project is highly valuable to correct the caveats before designing a large multicentric study and to ensure the adherence to the protocol in its future implementation in clinical practice.

The study has some limitations. We cannot rule out a potential selection bias when activating the application, related to its use at the neurologist's discretion, with the

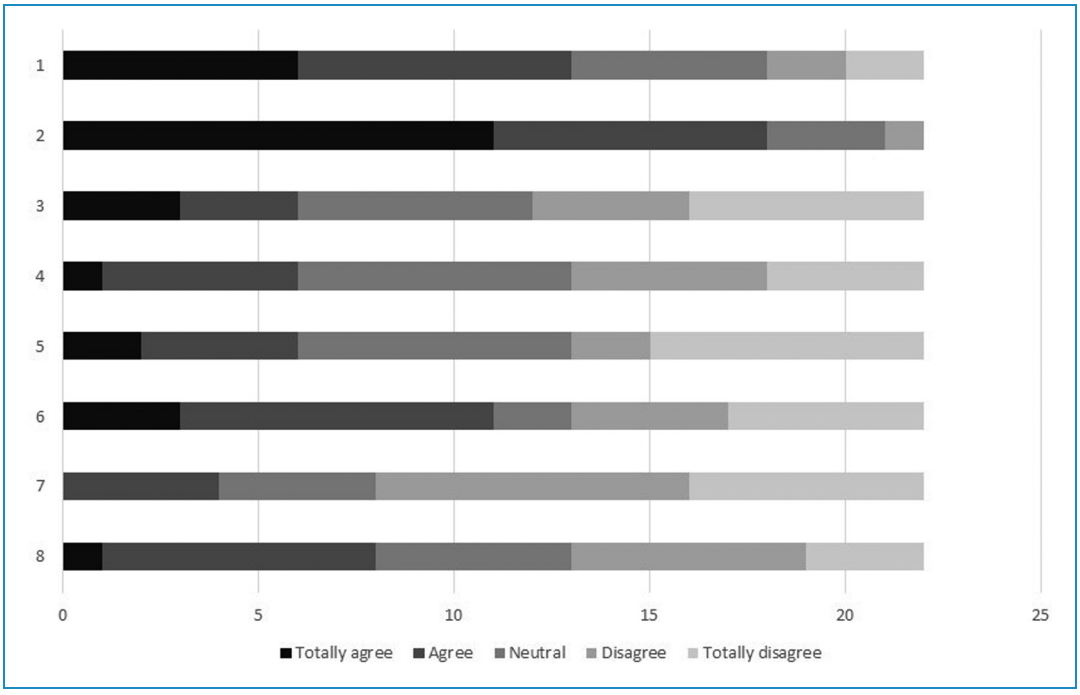

Figure 3. Answers to the satisfaction survey about the use of JOIN app. The numbers on the *x*-axis indicate the number of answers to each category of agreement for the question. The numbers on the *y*-axis are the questions asked. Questions are listed below:
1. I consider the collected information in the JOIN app should be transferred and recorded automatically into the patient's medical history.
2. I think that the JOIN app adds extra work to the existing protocol
3. I think using the JOIN app reduces time to assistance times
4. I consider using JOIN helpful for daily practice in day-to-day work
5. I consider the chat useful as a communication tool
6. I think that image visualisation facilitates the diagnosis and decision making
7. I find patient information about transfers and radiology tests faster than by conventional methods
8. I find using the JOIN app easy.

more skilled neurologists specialised in cerebrovascular diseases managing the stroke codes more diligently and using the app more frequently. It is highly likely that those neurologists more committed to stroke management were more willing to use the app. However, we cannot verify this hypothesis given that the users were anonymous. The higher number of thrombolysis treatments among the JOIN group and the differences in stroke subtype between study groups could also reflect a selection bias in activating the app. The lack of randomisation and blindness in this study could contribute to potential biases. Also, this was a single-centre study, which could preclude generalisation of our results. Moreover, the patient tracking system and the communication system with the EMS, which might contribute substantially to the efficiency of stroke care from the very beginning, had not been implemented for this trial. Finally, we cannot rule out some bias when answering the survey, with those physicians who use the app less giving a negative evaluation of the app to justify not using it. Data recorded in the survey do not allow a specific analysis to clarify this issue. Despite these limitations, this pilot study shows data on the use of the application in real conditions and compares these data with those from a control group in the same period, with results that suggest its usefulness. Moreover, the collected feedback from the stakeholders allows us to correct the possible caveats before the next steps for its implementation in daily clinical practice and to increase the engagement of all users.

In conclusion, this study suggests the potential utility of smartphone applications to monitor the workflow and to speed workflow metrics in acute stroke management by facilitating communication sharing of relevant clinical information and decision making among stroke team members in a comprehensive stroke centre. However, there is still a perception that use of the app increases the workload in stroke management, which translates into a low rate of recommendation for its use. Improving the interoperability and coordination between the app and the electronic clinical records is perceived as a potential aid to the clinical duties and might help encourage the use of the app among physicians. These results should be validated in randomised multicentric studies including different teams, management pathways and protocols.

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Contributorship: MAdeL and BF conceived the study, obtained funding and obtained ethical approval. RG-Z, BF, EdeC, GR-A, JR-P, RR, LC, EA, AF-P, PN, AA-M, BM and MAdeL were involved in patient recruitment. RG-Z, JU, JCS-C and MAdeL analysed data. RG-Z, JU and JCS-C wrote the first draft of the manuscript. ED-T revised critically the article. All authors reviewed and edited the manuscript and approved the final version of the manuscript

Declaration of Conflicting of Interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval: This study was approved by the Ethics Committee of La Paz University Hospital (Approval number PI-3475). Informed consent was not sought for the present study because it was intended to evaluate clinical management aspects and not patient-related data. Informed consent was waived by The Ethics Committee of La Paz University Hospital.

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