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The Latium acute stroke registry: data quality and validation of the NIH Stroke Scale in predicting in-hospital death

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Summary

Background and Purpose: The experimental phase of the stroke registry for the region of Lazio, completed in 2003, collected clinical data using an ad hoc survey on emergency room (ER) patients who presented with suspected stroke. We evaluated the accuracy and completeness of the data collected and assessed the validity of the National Institute of Health Stroke Scale (NIHSS) in predicting in-hospital mortality.

Methods and Results: Two different indicators were developed to evaluate the quality of the registry: the response (% ER patients surveyed with suspected stroke) and the coverage rates (% ER patients surveyed discharged with stroke). Their values by type of emergency service were respectively: first aid ER =59.3% and 45.5%; level one ER =39.7% and 27.6%; level two ER =17.2% e 12.0%. Stroke severity, age, type of emergency facility and time of arrival at the ER were associated with the accuracy and completeness of the registry.

The in-hospital mortality predictive model showed good discriminative ability (area under the receiver-operating characteristic (ROC) curve (AUC)=0.79 (95%CI 0.75, 0.84)) and good calibration (Hosmer-Lemeshow's goodness-of-fit (HL) test p=0.48). AUC and HL tests, estimated after applying the linear predictor to an external validation cohort, were 0.79 (95%CI 0.74, 0.84) and p=0.23 respectively.

Conclusions: Survey completeness and accuracy were associated with patient and facility characteristics, suggesting that it could be improved. The NIHSS calculated at ER admission is a good predictor of in-hospital mortality.

Key words: acute stroke, emergency room registry, data quality, National Institute of Health Stroke Scale

Introduction

Stroke is one of the most significant causes of death in the western world and the most significant cause of permanent disability with very high social costs [1,2]. The international scientific community has supported the development of stroke surveillance systems for many years. A surveillance system is one of the methods employed to describe stroke episodes, to compare them temporally and geographically, and to carry out etiological studies and to study therapy effectiveness. Multi-centre studies on stroke at the national and European level were the impetus for developing comparable data, which shared methodologies and quality standards[3-6]. These studies stressed the necessity of using standardized scales to identify the severity of a stroke (Cincinnati Pre Hospital Stroke Scale, National Institute of Health Stroke Scale-NIHSS,[7-9]) and of routinely collecting information on risk factors to ensure that the data may be used for planning primary and secondary prevention interventions and for assessing hospital benchmarks through the risk adjustment process. To this end, the World Health Organization proposed a universal standard methodology for organizing epidemiological surveillance [10]. In Italy, there are various registers that record information from clinical charts and interviews [11-20]. In the Lazio region a stroke surveillance system (SSS) has been in implementation since 2002, the methodology of which has been explained elsewhere [21].

The SSS utilizes current data from health information systems already in operation in the region (health emergency (HEIS), hospital discharge (HIS), outpatient records, mortality) and the new registry of acute stroke maintained by the

emergency rooms (ER) of the Lazio region.

The SSS of the Lazio region is being launched in three phases, the second of which is addressed in this study. The first phase was a pilot study, the second an experimental phase, and the last is the full-operations phase.The components considered in the various phases were: 1) developing a methodology that could integrate data which are currently all collected by the region with data from the registry for acute stroke 2) the planning and execution of a training program for ER health personnel (doctors and nurses) on stroke patient management and on the registry protocol.

The objective of this study was to evaluate the quality of the registry during the experimental phase, both its operational aspects and the accuracy and the completeness of the data collected with specific focus on whether the NIHSS is a valid tool to predict in-hospital mortality.

Materials and Methods

The experimental phase of the registry (from November 2002 to December 2003) involved a representative sample of hospitals with emergency services from across the region. Specifically, using a cluster sampling procedure stratified by ER levels [22], 15 facilities were selected from the 56 in the region, of which 6 were general hospital first aid facilities (ER first aid), 5 were emergency rooms with some specialized services (ER level one) and 4 were emergency rooms with extensive specialized services (ER level two).

A specialized "ad hoc" survey form was developed specifically for this registry. It recorded clinical information on symptom onset, risk factors, and the stroke severity scale (NIHSS). The NIHSS is based on 15 items, and it can be calculated only when all items are completed. Training courses on the management of acute stroke patients were conducted before the study began for the emergency health personnel involved, the results of which are reported elsewhere [23]. The courses provided training on clinical, diagnostic and therapeutic aspects of the Italian version of the NIHSS, to identify neurological deficits in stroke patients [24] and on the correct use of the "ad hoc" survey form. After the training session, each sampled facility began the experimental phase of the registry by recording clinical information on the survey form for each patient with suspected stroke symptoms (aphasias, hemianopsia, paralysis, ataxia, dysarthria, neglect) upon arrival in the emergency room, independently of whether the diagnosis of stroke is then confirmed at discharge from the ER.

The operational aspects of the registry were evaluated considering all suspected stroke patients treated at the ER sampled and all patients discharged with a diagnosis of stroke (ICD9-CM codes 430-436) from the same hospitals in the study period. Hence, the final cohort was made up of all patients registered in the information systems of the HEIS and HIS with suspected stroke or stroke. We developed two different indicators to evaluate the external quality of the registry: the registry response, defined as the ratio of registered patients over the total number of stroke cases treated in the ER; and the coverage of the registry, defined as the ratio of registered patients who also had a diagnosis of stroke at discharge over the total number of stroke cases discharged in the same period.The internal quality of the registry was evaluated by assessing the completeness of the information. A logistic regression model for survey data (which provided odds ratios (OR) with standard errors adjusted for clustering of the hospitals) was used to analyze the associations between some potential determinants and the likelihood of being registered in the ER. The potential determinants considered in the model were: demographic characteristics (age categories, gender); triage code (red/yellow, green, white/Not Assigned-NA) of the patient upon arrival to the ER, day and time of emergency visit (day/night, weekday/weekend/holiday) and type of emergency facility (first aid, ER level one, ER level two) used as an indicator of level of assistance provided.

On a subgroup of acute stroke patients (ICD9CM:430, 431,434, 436) discharged from the hospital, the validity of the NIHSS as a severity score to predict in-hospital death was assessed. We decided to focus our model on the NIHSS (categorised in 6 classes) and the two demographic variables most easily and readily accessible at admission to an ER, age (categorised in 4 classes) and sex. A logistic model for survey data was used on the original data (cohort of 2003). The performance of the model was measured by two dimensions: calibration (Hosmer-Lemeshows goodness-of-fit test – (HL)) and discrimination (area under the receiver operating characteristic (ROC) curve (AUC)) [25,26].A cohort of acute stroke patients admitted to the ER in 2004 was used to externally validate the model.The linear predictor estimated from the original data was used to calculate the probability of in-hospital death for each subject on the external validation dataset; calibration and

discrimination were then calculated. A further assessment of the calibration was performed by exploring more in detail the expected and observed ratios (E/O) for each category of the variables used in the model.The expected number of deaths was calculated by summing the estimated individual risk predicted by the model given the covariate values for each subject. The estimated ratios (E/O) were reported with 95% confidence intervals (CI) calculated with the use of the Poisson variance for the logarithm of the observed number of cases, as follows:

$$95\%\ \text{CIs} = \frac{E}{O} \cdot \exp\left(\pm 1.96 \sqrt{\frac{1}{O}} \right)$$

To calculate the probability of in-hospital death for each subject on external validation data set, the intercept was corrected to calibrate the model on 2004 risk.

The analysis was performed with STATA.8 (Stata corp. 2003).

Results

Overall results of the registry

Overall, 2584 patients were registered during the study period (Table 1). Of these, 1993 patients were diagnosed with stroke in the emergency room (HEIS), and 1411 had a diagnosis of stroke at time of discharge (HIS). The overall registry response rate was 1993/5949 (33.5%), and the coverage rate was 1411/6374 (22.1%).These rates varied greatly depending on the type of facility, ranging from 596/1005 (59.3%) and 349/767 (45.5%) for response and coverage rates respectively in first aid ERs, to 433/2518 (17.2%) and 372/3108 (12.0%) at level two ERs, with level one ER facilities falling between them, with rates of 964/2426 (39.7%) and 690/2499 (27.6%).These differences indicate the need to investigate why some patients were not registered, especially since completing the survey form for each patient was stipulated in the study's protocol.

Table 2 describes ER stroke patients, both registered and not, and lists some of the patients' characteristics. The distributions show that the patients with the following characteristics were less likely to be registered: <= 45 years old (86.0%), triaged red or white/NA (79.8%, 90.6%), arrived at night (74.1%) and who were treated at more specialized health facilities (ER level one 60.3%; ER level two 82.9%). All factors were analysed with a logistic regression model that provided the adjusted odds ratio for not being registered. The risk of not being registered was about three times greater when the patients were young (<45 years) than when patients were over 84 years of age (OR=2.5 95%CI: 1.5, 4.3); it was twice as high for green-triaged patients (OR=1.7 95%CI: 1.3, 2.3) and for red-triaged patients (OR=2.0 95%CI: 1.4, 2.9) than for yellow-triaged patients; it was about six times higher for patients with white triage or none given (OR=6.3 95%CI: 2. 6, 15.1). The risk of not being registered was significantly higher for night time arrivals (OR=1.5 95%CI: 1.4, 1.7). In addition, the risk of not being registered was about seven times higher for patients at level two facilities (OR=7.6 95%CI: 4.7, 12.3) and more than twice as high at level one facilities (OR=2.4 95%CI: 1.2, 4.9) compared to patients at first aid ERs. Patient gender was not a determining factor for registration. Weekend compared to weekday emergency room visits however decreased the risk of not being registered by 10% (OR=0.9 95%CI: 0.8, 1.0).

The same analysis was conducted on the cohort after excluding patients who died during the hospitalisation. The results (not reported) are practically identical to those just described.

As regard the completeness of the registry, the percentage of missing information from the "ad hoc" survey forms relative to comorbidities and to the NIHSS was about 10%. Information on smoking habits was missing 75% of the time. The degree of completeness depended on the type of emergency facility. Specifically, the greatest amount of missing information was found at ER level two facilities, around 19% for comorbidities and about 85% for smoking habits (not reported in table).

Both the survey form and the HIS register data on comorbid diseases are particularly relevant to define the clinical status of the stroke patient. For the cohort of registered patients whose stroke was confirmed during admission, all primary and secondary diagnoses listed in the emergency room chart were verified in the HIS. We excluded cases from the analyses of each specific disease that had "undetermined" listed on the survey form.

In the ER registry comorbid diseases were reported with the following percentages: atrial fibrillation 21.2%, diabetes 29.4%, hypercholesterolemia 31.3%, hypertension 74.9%. According to the HIS, comorbidities occurred much less frequently: hypercholesterolemia 6%, atrial fibrillation 16.0%, diabetes 23.5%, and hypertension 49.2%.

The sensitivity of the HIS for comorbities is low, varying from 9.1% for hypercholesterolemia, 53.2% for atrial fibrillation, 56.6% for hypertension, to 68.1% for diabetes (not reported in table).

Table 1. Description of the cohorts and response and coverage rates of the stroke registry, by type of emergency facility

Type of emergency facility				
Facilities Studied (n = 15)	**ER first aid**	**ER level one**	**ER level one**	**Total**
Patients Registered (survey form filled out)	729	1188	667	2584
Registered Patients with a stroke diagnosis in ER **(A)**	596	964	433	1993
Patients with a stroke diagnosis (on arrival) at the ER **(B)**	1005	2426	2518	5949
Registered Patients with diagnosis of stroke at discharge from the hospital and with a completed survey form **(C)**	349	690	372	1411
Patients with diagnosis of stroke at discharge from the hospital **(D)**	767	2499	3108	6374
Response to the registry (%) (A/B)	**59.3**	**39.7**	**17.2**	**33.5**
Registry coverage (%) (C/D)	**45.5**	**27.6**	**12.0**	**22.1**

ER= Emergency Room

Table 2. Description of the suspected stroke patient cohort treated at emergency facilities and the Odds Ratios (OR) of not having a survey form filled out

	Total N=5949	**With survey form n=1993**	**Without survey form n=3956**	**OR[a]**	**95% CI adjusted for clustering**
	N	%	%		
Age					
>=85	929	36.8	63.2	1	
75-84	2161	36.3	63.7	1.0	0.8, 1.3
65-74	1523	33.2	66.8	1.0	0.8, 1.3
45-64	1044	30.6	69.4	1.0	0.8, 1.3
<45	292	14.0	86.0	2.5	1.5, 4.2
Gender					
Male	3054	32.5	67.5	1	
Female	2890	34.5	65.5	1.0	0.9, 1.1
Triage					
Red	516	20.2	79.8	2.0	1.4, 2.9
Yellow	3856	37.3	62.7	1	
Green	1460	29.9	70.1	1.7	1.3, 2.3
White/NA	117	9.4	90.6	6.3	2.6, 15.1
Time of arrival					
6,31a.m.-8,30 p.m.	4737	35.4	64.6	1	
8,31p.m.-6,30 a.m.	1212	25.9	74.1	1.5	1.4, 1.7
Day of arrival					
Weekday	4314	32.9	67.1	1	
Weekend	1635	34.8	65.2	0.9	0.8, 1.0
Type of ER[b]					
First aid	1005	59.3	40.7	1	
Level One	2426	39.7	60.3	2.4	1.2, 4.9
Level Two	2518	7.1	82.9	7.6	4.7, 12.3

[a] OR adjusted by all the indicated variables; [b] Emergency Room

The validity of the NIHSS

There were 797 registered patients with a diagnosis of acute stroke (ICD9CM:430, 431, 434 and 436) who had completed the ad hoc form, and they were used to develop the in-hospital mortality model. In the external validation cohort (2004), 507 patients were selected with the same criteria as the original cohort (2003). In both populations the mean age was around 75 years and the proportion of female patients was around 49%. The mean values of the NIHSS were 10.4 (SD=8.5) and 9.4 (SD=8.0) respectively in the validation and original cohort. Also, the in-hospital death rate was higher in the validation cohort, 20.3% vs 15.6% (data not reported in table).

In Table 3, the univariate analysis shows a statistically significant association of in-hospital death with age and NIHSS. In the multivariate analysis, gender also had a statistically significant effect. The most important predictor was NIHSS, the risk of death increased the higher the NIHSS score (for the NIHSS category >32 with respect to <4, the OR was 22.7; 95%CI:7.9, 64.8), followed by age and gender. The calibration of the model showed no deviation from the expected number of deaths by decile of risk (HL test, p=0.483). The discriminative ability of the model was good (AUC=0.79 95%CI 0.75, 0.84). The coefficients of the model estimated from the original data set were used to predict the probability of in-hospital death on the validation data set. The calibration and discriminative ability estimated for the validation data set were similar to those estimated for the original data set (HL test p=0.23;AUC=0.79 95%CI 0.74; 0.84). Table 4 shows observed and expected numbers of deaths for the categories of the covariates (age, sex, NIHSS) in the validation dataset. The E/O ratios indicate that the model underestimates risk for patients under age 65 years, E/O=0.55 (95%CI 0.30, 0.99). There is no other statistically significant evidence that the number of patients observed in the age, gender and NIHSS categories are different from those expected.

Discussion

This study was the first attempt in Italy to maintain a registry that collects information on the clinical characteristics of acute stroke patients in emergency rooms as indicated by national guidelines[28]. A series of difficulties were encountered during data collection, often connected to reasons already cited in the scientific literature, such as the difficulty in diagnosing stroke in an emergency situation, and the inconsistent use of severity scales, useful in identifying the patient's risk level [29-31].

The analysis conducted for this paper above all highlights the difficulties of data collection for the stroke registry and investigated some of the possible causes by evaluating the internal and external quality of the information.

Table 3. Original acute stroke data set description and risk of in-hospital mortality

	n. of patient	sn. of deaths (%)	Crude OR	Adjusted OR	95% CI adjusted for clustering
Total	797	124 (15.6)			
Age groups					
‹65	117	6 (5.2)	1	1	
65-74	201	19 (9.5)	1.9	1.7	0.7, 4.1
75-84	339	61 (18.0)	4.0 [a]	3.1	1.5, 6.3
›=85	140	38 (27.1)	6. 8[a]	4.4	1.8, 10.9
Sex					
Male	415	59 (14.2)	1	1	
Female	382	65 (17.0)	1.2	0.7	0.5, 0.9
NIHSS[b] score					
‹=4	259	13 (5.0)	1	1	
5-8	211	16 (7.6)	1.6	1.5	0.9, 2.5
9-12	115	19 (16.5)	3.7 [a]	3.4	1.2, 9.3
13-15	66	14 (21.2)	5.1 [a]	4.5	1.8, 11.8
16-21	68	22 (32.3)	9.1 [a]	8.2	3.3, 20.7
22-31	61	30 (49.2)	18.3 [a]	16.0	8.7, 29.5
›=32	17	10 (58.8)	27.0 [a]	22.7	7.9, 64.8

[a] p‹0.05; b National Institute of Health Stroke Scale

Table 4. External validation of the predictive in-hospital mortality model

	n. of patient	Obs. deaths	Exp. deaths	Exp/Obs	95% CI	
Total	507	103				
Age groups						
‹65	77	11	6.0	0.55	0.30	0.99
65-74	132	13	17.1	1.32	0.76	2.27
75-84	205	34	44.5	1.31	0.94	1.83
›=85	93	45	35.4	0.79	0.59	1.05
Sex						
Male	260	38	49.7	1.31	0.95	1.80
Female	247	65	53.3	0.82	0.64	1.05
NIHSS[a] score						
‹=4	170	7	10.3	1.47	0.70	3.09
5-8	103	9	9.4	1.05	0.55	2.02
9-12	62	13	11.7	0.90	0.52	1.55
13-15	54	20	13.9	0.70	0.45	1.08
16-21	48	18	18.6	1.03	0.65	1.64
22-31	58	27	31.3	1.16	0.79	1.69
›=32	12	9	7.7	0.86	0.45	1.65

[a] National Institute of Health Stroke Scale

The first aspects evaluated were indicators of the response to and the coverage of the registry.

If we consider that the objective of the registry is to collect specific information for all cases of suspected stroke treated in emergency rooms, complete participation means a response rate of 100%. However, the response rate was much lower than that, and reveals significant differences between facilities related to their degree of specialization in emergency care. These results could be due to organizational realities of the different facilities and the health personnel's level of interest, and/or how committed they were to reaching the objectives of the registry.The coverage rate, at around 22%, was very low also. But the theoretical maximum value of coverage is also lower than 100%.This is due in part to the fact that often suspected stroke patients are identified as such only after being admitted to the hospital, therefore there is always some percentage missed by the registry, since patients are registered in the emergency room. While the registry will never achieve total coverage, improving agreement between the two information sources (ER and clinical discharge reports), by improving the rate of accurate stroke diagnoses in the emergency room, will increase its effectiveness.

The analysis showed that form completion is not fortuitous.There are in fact specific determinants of completing the "ad hoc" form, stroke severity and age, the type of emergency facility and time of arrival. These associations may indicate the existence of objective difficulties on the part of the health professionals in completing the form, particularly when faced with very ill patients and/or those who rarely suffer from stroke (young patients).

Evaluating the internal quality of the data also appears to confirm this difficulty, in terms of the completeness of the NIHSS, stroke risk factors, and in completing the entire "ad hoc" form. Data shows that level two ERs were the least likely to complete the "ad hoc" form. These facilities have a series of organizational challenges (i.e. a high patient to staff ratio) that make data collection difficult, which is seen a burden on completing more routine activities. Regarding the quality of risk factors recorded on the ad-hoc form, in particular comorbid diseases, while in general a disease-specific registry is more accurate than a routine administrative source, problems can arise when information on comorbid diseases is self-reported, and not confirmed by diagnostic tests, as frequently occurs in emergency rooms.The accuracy of self-reports of diseases such as diabetes and hypertension has been analysed in many studies [32-24]. They show that the level of accuracy varies a great deal among chronic diseases (i.e. self-reported diabetes is more accurate than for other chronic diseases) and that, for each disease, there are specific factors affecting the accuracy related to the demographic and clinical conditions of the patients. These considerations suggest that further studies are required to evaluate the accuracy of specific self-

reported chronic conditions and to assess the percentage of comorbidities listed on clinical charts that are based on self-report.

Finally, in this study, we have developed and validated a model predicting in-hospital mortality within the first hours after onset of acute stroke, which is at admission to the ER, using the NIHSS as a measure of initial stroke severity, age and gender of the patients. The HL test and area under the ROC curve indicate a good performance of the predictive in-hospital death model developed on the original data set. Calibration and discriminative ability are also good on the validation dataset after correcting for the higher mortality rate that was registered in 2004 with respect to 2003. Nevertheless, the ratio between observed and expected deaths shows some deviation from the null value (unity) in younger patients.This deviation may depend on the relative distributions of possibly important risk factors like comorbidities or prior stroke that were not included in the model and were not used as selection criteria. Overall these results suggest that the NIHSS calculated in the ER is a valid severity stroke score and that further studies on selected patient cohorts may be helpful to confirm the validity of its predictive value.

Scientific literature has already showed several studies that agree on the early predictive value of initial stroke severity and age for several outcomes[35,36]. They also underline the importance of externally validating the prognostic models [37,38].

The ability to identify the neurological deficits of each patient with suspected stroke using the NIHSS, besides providing information that is useful for clinical and therapeutic treatment of the individual patient, provides accurate data for epidemiological studies and health service comparisons through risk adjustment. This process can compare patient outcomes at different hospitals in groups of patients with similar baseline levels of risk [39].As suggested by other authors [40],if the NIHSS is not routinely completed for all cases of stroke, a bias in severity-adjustment of outcomes may occur.

In light of these considerations, it is necessary to develop a strategy for the full operation phase of the stroke surveillance system of the Lazio region. It appears that a registry covering the entire region that yields an acceptable level of accuracy is not yet feasible. Instead, it is more useful at this time to concentrate and focus organizational, educational, and economic resources to create registries in a few selected emergency facilities.

Currently, the regional health authority of Lazio is working on the implementation of the third phase of the SSS by identifying a network of emergency facilities to function as sentinels, with whom to continue collaboration and conduct training courses on the careful and accurate collection of the information reported on the specialized stroke form. In the future the registry will be extended to other facilities.

Author contributions

All authors contributed substantially to the study's conception and design, acquisition of data, analysis and data interpretation, drafting or revising the article for content, and final approval of the version to be published.

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Key points:

- Routine collection of information on risk factors and severity of the acute stroke through an ER registry makes data available for planning public health interventions for stroke.
- The NIHSS completed in the Emergency Room gives a valid severity stroke score.
- A regional network of "sentinel" emergency rooms needs to be created to provide a careful and accurate collection of the risk factors and NIHSS information.

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