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The emergency department quality improvement program improves the prognosis of patients with stroke in Taiwan: A nationwide cohort study

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In 2012, Taiwan implemented the Emergency Department Quality Improvement Program (EDQIP) to enhance the quality of care for patients with acute ischemic stroke (AIS). This retrospective study evaluated the program's effectiveness using data from the National Health Insurance Research Database. AIS patients were classified into three groups: a pre-implementation group (2011), and a post-implementation group (2013–2015), which was further subdivided into EDQIP and non-EDQIP groups based on hospital participation and receipt of performance-based incentives. Among 169,434 AIS cases identified between 2013 and 2015, 64,574 patients met the inclusion criteria. Compared to the non-EDQIP group, patients in the EDQIP group demonstrated a 9% absolute reduction in the 30-day mortality rate (6% vs. 15%; adjusted hazard ratio [aHR] = 0.40, 95% confidence interval [CI] = 0.32–0.50) and a 2% absolute reduction in the 72-hour emergency department revisits rate (5% vs. 7%). Additionally, the EDQIP group showed a 9% absolute reduction in 30-day mortality rate compared to the pre-EDQIP group (6% vs. 15%; aHR = 0.39, 95% CI = 0.31–0.49). These findings suggest that the EDQIP may be associated with improved clinical outcomes for AIS patients in Taiwan and may serve as a model for similar quality improvement initiatives worldwide.

Keywords Health policy, Quality improvement program, Acute ischemic stroke, Emergency department, Thrombolytic therapy

Stroke is the second leading cause of disability and mortality worldwide, with its highest burden observed in low- and middle-income countries[1]. In 2016, 13.7 million new cases of stroke were reported worldwide, with approximately 87% involving ischemia, 10% involving intracranial hemorrhage, and 3% involving subarachnoid hemorrhage[2,3]. In response to the growing burden of acute stroke, Taiwan launched the Emergency Department Quality Improvement Program (EDQIP) in 2012 to enhance the quality of emergency care, particularly for time-sensitive conditions such as acute ischemic stroke (AIS). The EDQIP incorporated performance-based financial incentives and aimed to improve key metrics such as timely thrombolysis, emergency department (ED) overcrowding, and critical care transfers[4]. In 1995, the National Institute of Neurological Disorders and Stroke Trial revealed that patients with AIS who received an intravenous recombinant tissue plasminogen activator (rt-PA) within 3 h of symptom onset experienced a significant reduction in disability at 90 days, with 50% of those treated having minimal or no disability as compared with 38% of the control group[5]. Since 2010, various treatments for stroke have been developed to extend the therapeutic time window for reperfusion therapy and improve patient outcomes. These treatments include endovascular thrombectomy and neuroprotective agents[6]. In 2020, the American Heart Association and American Stroke Association endorsed the use of intravenous rt-PA within an extended time window of 4.5 h[7,8]. Despite the efficacy of intravenous rt-PA in improving outcomes,

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fewer than 5% of patients with AIS worldwide receive intravenous thrombolytic therapy within the selected therapeutic time window, and fewer than 100,000 endovascular thrombectomy procedures were performed worldwide in 2016[3]. In Taiwan, the utilization rate of thrombolytic therapy increased from 0.03% in 2003 to 1.51% in 2010, with only 0.6% of 394,988 patients with AIS receiving thrombolytic therapy during that period[9]. More broadly, recent studies have highlighted the importance of optimizing ED performance to improve time-sensitive care delivery, including predictive modeling for ED visit patterns[10]strategies to improve care for older adults in the ED[11]and the association between ED boarding delays and 30-day mortality[12]. These findings underscore the critical role of ED systems in improving outcomes for patients with acute conditions such as AIS.

The EDQIP was designed to improve emergency care quality by reducing overcrowding in EDs, increasing the efficiency of patient transfer and ED management, and improving the outcomes of patients with critical conditions such as out-of-hospital cardiac arrest, acute myocardial infarction, AIS, major trauma, acute aortic disease, and severe sepsis[13]. As part of the program, patients with AIS who received thrombolytic therapy within 60 min of arrival at the ED were considered eligible for additional financial incentives. EDQIP offers a distinct model that emphasizes emergency department performance and time-sensitive financial incentives. Despite these benefits, the efficacy and impact of the EDQIP on the prognosis of patients with stroke has not yet been evaluated, and little studies have examined ED-based stroke quality improvement programs using nationwide population data in Asian healthcare systems. Therefore, this study aimed to examine the impact of the EDQIP on the overall prognosis of patients with stroke.

Results

Comparison of the EDQIP and non-EDQIP groups after the EDQIP's implementation

A total of 169,434 patients who visited an ED with a diagnosis of stroke between 2013 and 2015 were initially identified. After patients with a history of stroke ($n = 54,161$), patients with incomplete data ($n = 2,406$), patients under 20 years of age ($n = 314$), and patients who were not admitted to a hospital were excluded, 64,574 patients were ultimately included for analysis (Fig. 1). Among these patients, 1,414 applied for additional financial incentives within the EDQIP, whereas 63,160 did not. The majority of the patients were men, with a large proportion aged above 75 years. Compared with the patients in non-EDQIP group, those in the EDQIP group were more likely to be aged between 55 and 74 years. In addition, patients in the EDQIP group had a higher monthly income and were more likely to reside in highly urbanized areas compared with those in the non-EDQIP group. They also required more intensive care unit (ICU) care compared with their non-EDQIP counterparts. Table 1 presents a detailed comparison of patient characteristics between the two groups. After 1:4 propensity score matching was performed, no significant differences in baseline characteristics were observed between the EDQIP and non-EDQIP groups.

Table 2 presents the prognosis of patients with AIS. Compared with the non-EDQIP group, the EDQIP group had 9% reduction of 30-day mortality rate (6% vs. 15%, adjusted hazard ratio[aHR] = 0.4, 95% confidence interval [CI] = 0.32–0.50, $p < 0.001$). Figure 2 presents the multivariate-adjusted 30-day cumulative survival probabilities of the EDQIP and non-EDQIP groups. In addition to more favorable survival outcomes, the EDQIP group exhibited an absolute reduction of 6 days in hospital length of stay (LOS) than that of the non-EDQIP group (12 [8–34] vs. 18 [7–27] days, ratio = 0.82, 95% CI = 0.78–0.87, $p < 0.001$). Similarly, the median ICU LOS was 2 days shorter for patients in the EDQIP group than for those in the non-EDQIP group (2[2–4] vs. 4[2–7] days, ratio = 0.69, 95% CI = 0.65–0.72, $p < 0.001$). Patients in the EDQIP group demonstrated a 2% lower rate of revisiting the ED within 72 h after discharge compared with those in the non-EDQIP group (5% vs. 7%, aOR = 0.74, 95% CI = 0.57–0.94, $p = 0.016$).

Comparison of patients with stroke before and after the EDQIP's implementation

A total of 55,604 patients presented to EDs with a diagnosis of stroke in 2011. Of these patients, 14,581 with a history of stroke, 151 under 20 years of age, 981 with incomplete data, and 18,842 not admitted to a hospital were excluded from the study. Ultimately, 21,049 patients were included for analysis (Fig. 1). Compared with the EDQIP group, the pre-EDQIP group comprised a higher proportion of patients aged 75 years and above. In addition, the pre-EDQIP group exhibited higher CCI scores than those of the EDQIP group. After 1:2 propensity score matching, no significant differences in baseline patient characteristics were observed between the pre-EDQIP and EDQIP groups (Table 3).

Table 4 presents a comparison of the patients' prognoses after stroke for the pre-EDQIP (2011) and EDQIP group. Patients in the EDQIP group exhibited an absolute 9% reduction in 30-day mortality rates compared with those in the pre-EDQIP group (6% vs. 15%, aHR = 0.39, 95% CI = 0.31–0.49, $p < 0.001$). Figure 3 presents the multivariate-adjusted 30-day cumulative survival probabilities of patients with AIS in the two groups. The EDQIP group exhibited an absolute reduction of 5 days in hospital LOS (12 [8–33] vs. 17[7–27] days, ratio = 0.83, 95% CI = 0.78–0.89, $p < 0.001$) and 2 days in ICU LOS (2 [2–4] vs. 4 [2–7] days, ratio = 0.70, 95% CI = 0.66–0.73, $p < 0.001$) compared with the pre-EDQIP group. In addition, the proportion of patients returning to the ED within 72 h after discharge was 2% lower in the EDQIP group than in the pre-EDQIP group (5% vs. 7%, aOR = 0.71, 95% CI = 0.54–0.92, $p = 0.011$).

Discussion

In this study, patients with stroke who received additional incentives within the EDQIP exhibited significantly more favorable outcomes compared with those who did not. Specifically, the EDQIP group exhibited a lower risk of 30-day mortality compared with the non-EDQIP group. Additionally, the EDQIP group experienced shorter hospital and ICU LOS and a lower likelihood of returning to the ED within 72 h after discharge compared with

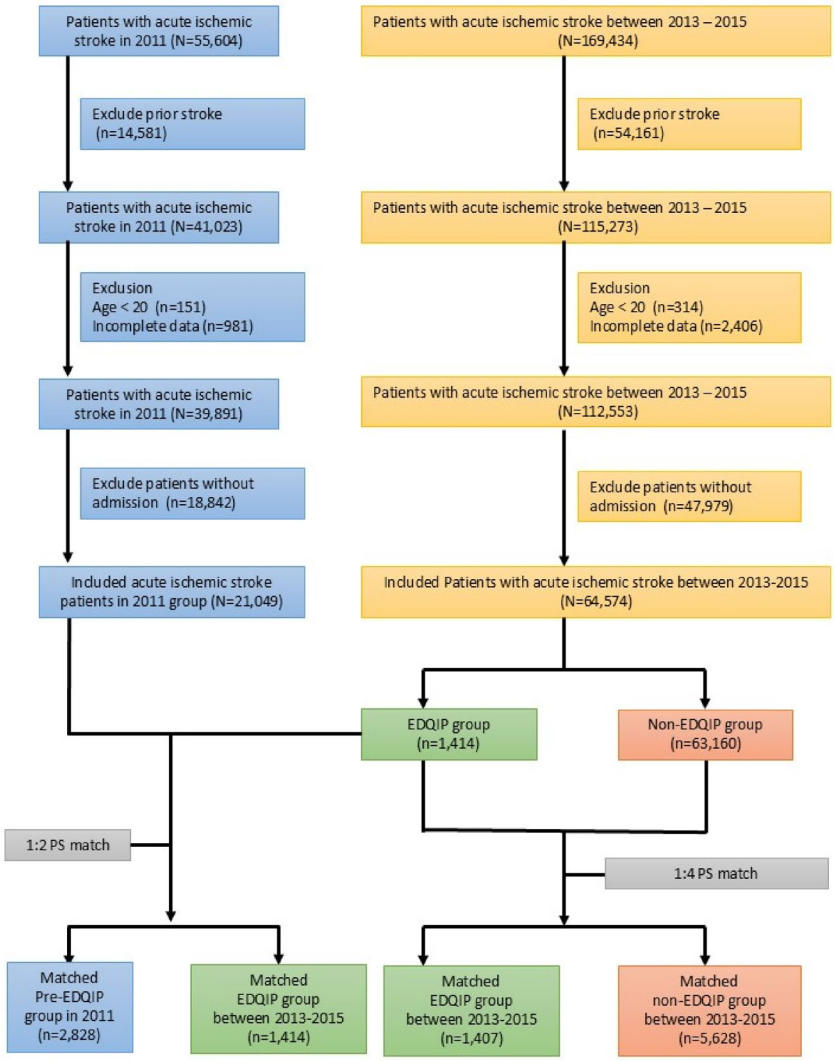

Fig. 1. Patient enrollment flowchart.

the non-EDQIP group. To the best of our knowledge, this is the first nationwide, population-based study in an Asian context to evaluate the impact of an ED-focused quality improvement program on stroke outcomes.

Evidence suggests that the EDQIP improves the outcomes of patients with AIS. Transferring patients with AIS to a stroke center for management can reduce their mortality rates and increase their likelihood of receiving t-PA treatment[14]. Appropriate quality improvement initiatives have been found to enhance the effectiveness of emergency treatment for patients with AIS[15]. Additionally, pay-for-performance incentives in health insurance systems have been found to be associated with improved outcomes in the management of various conditions, such as diabetes and chronic kidney disease, by providing financial incentives for high-quality care[16–18]. Within the EDQIP, incentives are provided for AIS cases with National Institutes of Health Stroke Scale (NIHSS) scores of 4–25 who received r-tPA injections[13]. In line with these findings, our study demonstrated that patients with stroke who received EDQIP incentives exhibited more favorable outcomes compared with those who were not eligible for additional incentives within the EDQIP. This improvement may be attributed to several mechanisms. First, the financial incentives tied to timely r-tPA administration encouraged hospitals to streamline AIS workflows and improve compliance with evidence-based AIS treatment guidelines. Second, because most hospitals treating acute conditions in Taiwan are contracted with the National Health Insurance (NHI) program, they tend to actively align their clinical practices with NHI policy initiatives. Studies have shown that healthcare providers in Taiwan exhibit high compliance with pay-for-performance programs under the NHI[19]. Third, EDQIP participation is often linked to hospital accreditation criteria, which further drives institutions to monitor and improve metrics such as the number of rt-PA administrations and the door-to-needle time. Collectively, these factors may have contributed to faster treatment, more standardized care, and improved coordination in emergency settings for AIS.

Our findings not only underscore the effectiveness of the EDQIP in improving the outcomes of patients with AIS but also lay the foundation for broader implications in healthcare practices worldwide. Unlike similar programs, such as the Get With The Guidelines—Stroke program in the United States, the EDQIP demonstrates

	Pre-PSM							Post-PSM (1:4)						
	Overall		EDQIP		Non-EDQIP			overall		EDQIP		Non-EDQIP		
Variables	N	%	N	%	N	%	SMD*	N	%	N	%	N	%	SMD*
Total	64,574	100	1414	2	63,160	98		7035	100	1407	20	5628	80	
Sex														
Female	25,584	40	529	2	25,055	98	0.046	2596	37	528	20	2068	80	0.016
Male	38,990	60	885	2	38,105	98	0.046	4439	63	879	20	3560	80	0.016
Age														
20–44	2110	3	62	3	2048	97	0.060	313	4	62	20	251	80	0.003
45–54	5911	9	151	3	5760	97	0.052	714	10	151	21	563	79	0.024
55–64	13,408	21	376	3	13,032	97	0.141	1776	25	369	21	1407	79	0.028
65–74	15,616	24	428	3	15,188	97	0.140	2211	31	428	19	1783	81	0.027
≧75	27,529	43	397	1	27,132	99	0.315	2021	29	397	20	1624	80	0.014
Monthly salary (NTD)														
≦20,008	20,830	32	393	2	20,437	98	0.100	1965	28	393	20	1572	80	0.000
NT$20,009 ~ 28,800	29,890	46	658	2	29,232	98	0.005	3340	47	656	20	2684	80	0.021
NT$22,801 ~ 36,300	4113	7	104	3	4009	97	0.040	487	7	101	21	386	79	0.013
NT$36,301 ~ 45,800	4838	7	137	3	4701	97	0.080	675	10	135	20	540	80	0.000
≧NT$45,801	4903	8	122	2	4781	98	0.039	568	8	122	21	446	79	0.027
Urbanization of residence areas														
1	9859	15	252	3	9607	97	0.070	1179	17	252	21	927	79	0.038
2	16,189	25	348	2	15,841	98	0.011	1787	25	348	19	1439	81	0.019
3	12,343	19	257	2	12,086	98	0.025	1293	18	257	20	1036	80	0.004
4	13,491	21	327	2	13,164	98	0.055	1533	22	320	21	1213	79	0.029
≧5	12,692	20	230	2	12,462	98	0.090	1243	18	230	19	1013	81	0.044
CCI score														
0	2509	4	32	1	2477	99	0.096	151	2	32	21	119	79	0.011
1	16,575	26	457	3	16,118	97	0.150	2193	31	450	21	1743	79	0.022
2	14,521	22	337	2	14,184	98	0.033	1669	24	337	20	1332	80	0.007
≧3	30,969	48	588	2	30,381	98	0.131	3022	43	588	19	2434	81	0.029
Level of health care organization														
Medical center	21,498	33	552	3	20,946	97	0.123	2789	39	551	20	2238	80	0.012
Regional hospital	33,189	51	778	2	32,411	98	0.074	3848	54	772	20	3076	80	0.004
District hospital	9887	15	84	1	9803	99	0.313	398	6	84	21	314	79	0.017
Ownership of health care organization														
Public	44,863	69	1090	2	43,773	98	0.176	5511	78	1084	20	4427	80	0.039
Non-public	19,711	31	324	2	19,387	98	0.176	1524	22	323	21	1201	79	0.039
ICU														
No	49,457	77	44	0	49,413	100	2.373	220	3	44	20	176	80	0.000
Yes	15,117	23	1370	9	13,747	91	2.373	6815	96	1363	20	5452	80	0.000

Table 1. Characteristics of patients with acute ischemic stroke from 2013 to 2015 who received additional financial incentives within the emergency department quality improvement program and those who did not. *Standardized mean difference (SMD) ≤ 0.1 indicated no significant difference between the two groups. Emergency Department Quality Improvement Program (EDQIP); propensity score matching (PSM); Charlson comorbidity index (CCI); intensive care unit (ICU).

a uniform pattern of improved patient outcomes through well-structured quality improvement initiatives[20,21]. Comparable efforts have also been implemented internationally, including the Canadian Alteplase for Stroke Effectiveness Study, which evaluated thrombolysis performance across multiple centers[7]; the United Kingdom's Sentinel Stroke National Audit Programme, which emphasized multidisciplinary care benchmarks and continuous audit feedback[22,23]; and Australia's Stroke Foundation National Audit, which focused on system-wide care quality indicators and adherence to clinical guidelines[24]. Compared to these programs, EDQIP offers a distinct model by incorporating time-based financial incentives within an emergency department–centered framework. It also demonstrated a major economic impact, with major reductions in hospital and ICU LOS resulting in substantial cost savings for the healthcare system[25]. These savings can be redirected to other critical areas, further enhancing the overall quality of healthcare delivery. Future studies should prioritize examining long-term outcomes and patient-reported measures to provide a more comprehensive assessment of the program's sustained impact on patient health.

Variables	N					P	Unadjusted				Adjusted			
								95%CI		P		95%CI		P
30 days mortality		Mortality(n)		%		Log-rank test < 0.001	HR				aHR			
Non-EDQIP group	5628	834		15			1.00				1.00			
EDQIP group	1407	87		6			0.40	0.32	0.50	< 0.001	0.40	0.32	0.50	< 0.001[a]
Hospital length of stay		Mean	STD	Median	IQR	Wilcoxson sign rank test < 0.001	Ratio				Ratio			
Non-EDQIP group	5628	25.49	36.12	18	26(8–34)		1.00				1.00			
EDQIP group	1407	20.92	32.06	12	20(7–27)		0.82	0.77	0.87	< 0.001	0.82	0.78	0.87	< 0.001[b]
ICU length of stay		Mean	STD	Median	IQR	Wilcoxson sign rank test < 0.001	Ratio				Ratio			
Non-EDQIP group	5628	5.84	5.92	4	5(2–7)		1.00				1.00			
EDQIP group	1407	3.68	4.13	2	2(2–4)		0.68	0.63	0.74	< 0.001	0.69	0.65	0.72	< 0.001[b]
72-hour ED revisits		Revisits (n)		%		McNemar's test	OR				aOR			
Non-EDQIP group	5628	400		7		0.01	1.00				1.00			
EDQIP group	1407	73		5			0.73	0.57	0.94	0.014	0.74	0.57	0.94	0.016[c]

Table 2. Prognosis of patients with acute ischemia stroke who received additional care incentives within the emergency department quality improvement program and those who did not. Emergency Department Quality Improvement Program (EDQIP); intensive care unit (ICU); Emergency department (ED); standard deviation (STD), interquartile range (IQR). Multivariate model adjusted for age, sex, monthly income, urbanization level, CCI score, hospital level, hospital type, and ICU admission status. [a]Stratified Cox proportional-hazards regression. [b]Multiple regression with logarithmic transformation and generalized estimating equations. [c]Conditional logistic regression.

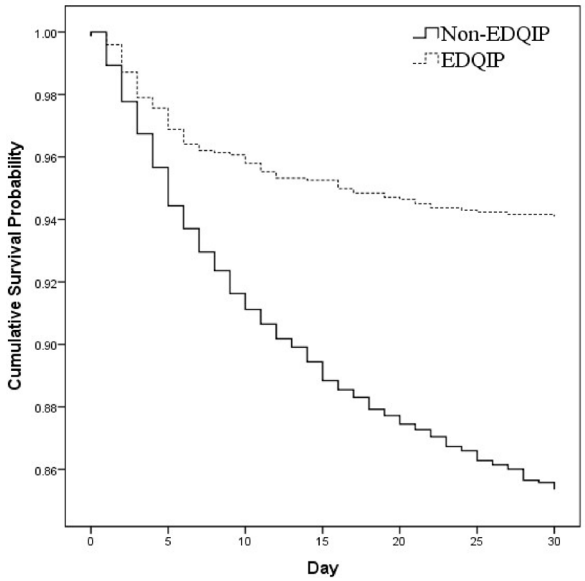

Fig. 2. Multivariate adjusted 30-day cumulative survival probabilities of patients with acute ischemic stroke between 2013 and 2015, following the launch of the Emergency Department Quality Improvement Program in 2012. Patients who were eligible for additional EDQIP care incentives (EDQIP group) demonstrated significantly higher survival probabilities compared with those who were not (non-EDQIP group).

The success of the EDQIP may serve as a valuable model for enhancing the quality of care for patients with AIS in developing countries. In these regions, challenges such as limited access to imaging technology for rapid diagnoses, underdeveloped transportation networks, and insufficient emergency medical services often delay patient access to specialized stroke centers, thereby hindering the timely administration of thrombolytic therapy[26,27]. With the implementation of quality improvement policies, such as financial support for the stroke care infrastructure, these barriers can be addressed, leading to improved outcomes for patients with AIS. To achieve these goals, governments and international organizations should explore alternative funding models, including public–private partnerships and tiered financial incentives, to facilitate access to stroke care[28]. In addition to financial investment, other policy strategies may include establishing regional AIS referral networks

	Pre-PSM							Post-PSM (1:2)						
	Overall		Pre-EDQIP group		EDQIP group			Overall		Pre-EDQIP group		EDQIP group		
Variables	N	%	N	%	N	%	SMD*	N	%	N	%	N	%	SMD*
Total	22,463	100	21,049	94	1414	6		4242	100	2828	67	1414	33	
Sex														
Female	8959	40	8430	94	529	6	0.054	1614	38	1085	67	529	33	0.020
male	13,504	60	12,619	93	885	7	0.054	2628	62	1743	66	885	34	0.020
Age														
20–44	709	3	647	91	62	9	0.069	181	4	119	66	62	34	0.009
45–54	1990	9	1839	92	151	8	0.066	431	10	280	65	151	35	0.026
55–64	4621	21	4245	92	376	8	0.152	1079	25	703	65	376	35	0.040
65–74	5709	25	5281	93	428	7	0.116	1292	30	864	67	428	33	0.006
≧75	9434	42	9037	96	397	4	0.314	1259	30	862	68	397	32	0.053
Monthly salary (NTD)														
≦20,008	9400	42	9007	96	393	4	0.318	1221	29	828	68	393	32	0.033
NT$20,009 ~ 28,800	8659	39	8001	92	658	8	0.173	1980	47	1322	67	658	33	0.004
NT$22,801 ~ 36,300	1312	6	1208	92	104	8	0.065	311	7	207	67	104	33	0.001
NT$36,301 ~ 45,800	1558	7	1421	91	137	9	0.107	386	9	249	65	137	35	0.031
≧NT$45,801	1534	7	1412	92	122	8	0.072	344	8	222	65	122	35	0.028
Urbanization of residence areas														
1	3252	14	3000	92	252	8	0.097	702	17	450	64	252	36	0.051
2	5845	26	5497	94	348	6	0.035	1100	26	752	68	348	32	0.045
3	4267	19	4010	94	257	6	0.022	766	18	509	66	257	34	0.005
4	4729	21	4402	93	327	7	0.053	945	22	618	65	327	35	0.030
≧5	4370	19	4140	95	230	5	0.089	729	17	499	68	230	32	0.037
CCI														
0	692	3	660	95	32	5	0.054	99	2	67	68	32	32	0.007
1	5662	25	5205	92	457	8	0.169	1276	30	819	64	457	36	0.073
2	5222	23	4885	94	337	6	0.015	1002	24	665	66	337	34	0.007
≧3	10,887	48	10,299	95	588	5	0.148	1865	44	1277	68	588	32	0.072
Level of health care organization														
Medical center	7114	32	6562	92	552	8	0.165	1651	39	1099	67	552	33	0.004
Regional hospital	11,826	53	11,048	93	778	7	0.051	2338	55	1560	67	778	33	0.003
District hospital	3523	16	3439	98	84	2	0.335	253	6	169	67	84	33	0.001
Ownership of health care organization														
Public	15,954	71	14,864	93	1090	7	0.813	3298	78	2208	67	1090	33	0.024
Non-public	6509	29	6185	95	324	5	0.099	944	22	620	66	324	34	0.024
ICU														
No	4711	21	4667	99	44	1	0.599	132	3	88	67	44	33	0.000
Yes	17,752	79	16,382	92	1370	8	0.599	4110	97	2740	67	1370	33	0.000

Table 3. Characteristics of patients with acute ischemic stroke in 2011 and those who received additional care incentives within the emergency department quality improvement program from 2013 to 2015. *Standardized mean difference (SMD) ≤ 0.1 indicated no significant difference between the two groups. Emergency Department Quality Improvement Program (EDQIP); propensity score matching (PSM); Charlson comorbidity index (CCI); intensive care unit (ICU);.

to facilitate timely transfers, supporting the development of certified stroke centers across geographic zones, and expanding the use of telemedicine to assist with real-time stroke diagnosis and treatment, particularly in rural or underserved areas[29,30]. These strategies could serve as scalable components of a broader stroke care framework adapted to different healthcare infrastructures. Overall, our findings provide valuable insights for future policy development aimed at enhancing the quality of AIS treatment in resource-limited settings. However, it is important to note that only a small proportion of AIS patients received EDQIP incentives during the study period, reflecting the early-stage adoption of thrombolysis and stringent eligibility criteria. As such, while the program showed promise in improving outcomes among this selected subgroup, the generalizability of our findings to the broader AIS population may be limited. Future evaluations incorporating broader program participation and real-world implementation data will be essential to assess its impact at scale.

Variables	N					P	Unadjusted				Adjusted			
								95%CI		P		95%CI		P
30-day mortality		Mortality (n)		%		Log-rank test	HR				aHR			
pre-EDQIP group	2828	435		15		< 0.001	1.00				1.00			
EDQIP group	1414	87		6			0.38	0.31	0.48	< 0.001	0.39	0.31	0.49	< 0.001[c]
Hospital length of stay		Mean	STD	Median	IQR	Wilcoxson sign rank test	Ratio				Ratio			
pre-EDQIP group	2828	25.70	43.41	17	25(8–33)	< 0.001	1.00				1.00			
EDQIP group	1414	20.86	31.99	12	20(7–27)		0.83	0.78	0.89	< 0.001	0.83	0.78	0.89	< 0.001
ICU length of stay		Mean	STD	Median	IQR	Wilcoxson sign rank test	Ratio				Ratio			
pre-EDQIP group	2828	5.73	5.84	5	5(2–7)	< 0.001	1.00				1.00			
EDQIP group	1414	3.68	4.12	2	2(2–4)		0.69	0.64	0.75	< 0.001	0.70	0.66	0.73	< 0.001
72-hour ED revisit		Revisits (n)		%		McNemar's test 0.006	OR				aOR			
pre-EDQIP group	2828	212		7			1.00				1.00			
EDQIP group	1414	74		5			0.70	0.54	0.91	0.008	0.71	0.54	0.92	0.011

Table 4. Prognosis of patients with acute ischemic stroke before and after the implementation of the emergency department quality improvement program. Emergency Department Quality Improvement Program (EDQIP); intensive care unit (ICU), Emergency department (ED); standard deviation (STD), interquartile range (IQR). Multivariate model adjusted for age, sex, monthly income, urbanization level, CCI score, hospital level, hospital type, and ICU admission status. [a]Stratified Cox proportional-hazards regression. [b]Multiple regression with logarithmic transformation and generalized estimating equations. [c]Conditional logistic regression.

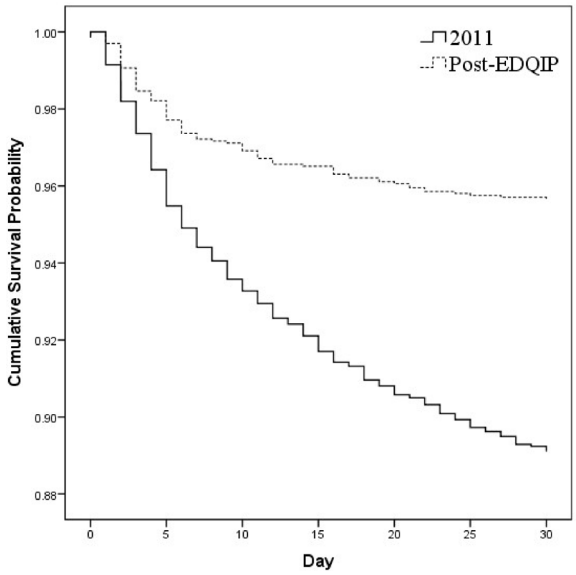

Fig. 3. Multivariate adjusted 30-day cumulative survival probabilities of patients with acute ischemic stroke in 2011 and those who received additional care incentives within the Emergency Department Quality Improvement Program between 2013 and 2015. The EDQIP group exhibited significantly more favorable survival outcomes compared with the pre-EDQIP cohort.

Although we used a nationwide database to evaluate the effectiveness of the EDQIP, this study has several limitations. First, despite the effectiveness of *ICD-9-CM* codes in the identification of stroke[31]the severity of AIS could not be directly measured using the National Health Insurance Research Database (NHIRD). Although the EDQIP group exhibited a shorter hospital LOS and a lower proportion of ICU admissions compared with the non-EDQIP group, the effectiveness of the EDQIP may have been underestimated because patients with an NIHSS score below 4 did not receive r-tPA and may have also been excluded from the EDQIP. In addition, because the EDQIP incentives only applied to patients with NIHSS scores between 4 and 25, the study population likely excluded those with very mild or very severe strokes, thereby biasing the EDQIP group toward patients with moderate stroke severity. To partially account for stroke severity, ICU admission status was included in the propensity score matching and multivariate models as a proxy variable. Furthermore, since the EDQIP group was defined based on receipt of rt-PA therapy with associated financial incentives, the observed effects may

reflect both treatment receipt and program participation, potentially confounding the impact of the EDQIP itself. Second, physician blinding was not feasible in this study, raising a concern that physicians may have been more attentive to patients eligible for EDQIP incentives. Third, although this study was retrospective in nature, selection bias could not be completely avoided. Notably, patients in the EDQIP group were more likely to be aged between 55 and 74 years, whereas those in the non-EDQIP group were more likely to be aged 75 years or above. In addition, a greater proportion of patients in the non-EDQIP group exhibited a CCI score of 3 or higher. To minimize possible selection bias, propensity score matching and multivariate analysis were used to adjust for potential confounders, including ICU admission status as a proxy for severity. Nevertheless, residual confounding from unmeasured variables—such as stroke severity scores (e.g., NIHSS) and patient functional status—may still exist. This limitation should be considered when interpreting the observed associations. Finally, because we used data only from the NHIRD, our findings may not be generalizable to populations from other countries. In addition, because only 2.2% of patients with AIS received EDQIP-related incentives, the study population represents a highly selected AIS patient group. Therefore, the findings should not be generalized to all patients with AIS but rather interpreted as the potential benefit among patients who met EDQIP eligibility and thrombolysis therapy treatment criteria. Future evaluations incorporating broader program participation and real-world implementation data will be essential to assess the program's effectiveness at scale. Additionally, subgroup analyses stratified by age, comorbidity burden, or stroke subtype should be explored to better identify which populations benefit most from ED-based quality improvement programs such as EDQIP.

In conclusion, EDQIP was associated with improved the outcomes of patients with AIS in Taiwan, including lower 30-day mortality rates, reduced hospital and ICU LOS, and 72-h ED revisits. While these findings support the potential value of quality improvement initiatives in enhancing stroke care, they should be interpreted with caution due to possible confounding by indication. Nevertheless, the results highlight the promise of structured, incentive-based programs for integration into broader health-care systems.

Methods

Study design and data sources

This retrospective study was conducted to explore the prognosis of patients with AIS, comparing those who received care incentives within the EDQIP with those who did not. Data was obtained from the NHIRD, which is maintained by the Health and Welfare Data Science Center. Launched in 1995, Taiwan's National Health Insurance Program covers 99.93% of the entire population[32,33]. The NHIRD has been widely used in research, and the accuracy of its data has been validated in previous studies[34].

Study participants

Patients who presented with their first episode of AIS at an ED between 2011 and 2015 were included in the study. AIS was identified using the principal diagnosis code for cerebral artery occlusion (*International Classification of Diseases*, *Ninth Revision*, *Clinical Modification* [*ICD-9-CM*] codes 433.x to 434.x). Patients under 20 years of age, patients with a history of AIS, and patients with incomplete data were excluded from the analysis. Patients who were not admitted to a hospital were also excluded. Because the EDQIP was launched in 2012, patients with AIS diagnosed in 2011 were assigned to a group called the pre-EDQIP group. Patients with AIS diagnosed between 2013 and 2015 were further assigned to EDQIP and non-EDQIP groups depending on whether they received rt-PA therapy and whether they were eligible for additional financial incentives within the EDQIP (identified by code P4601B).

Relevant variables

To accurately determine the participants' characteristics, demographic information, including age and sex, was retrieved from the NHIRD. Comorbidities were identified using *ICD-9-CM* codes for conditions such as hypertension and stroke and diseases listed in the Charlson Comorbidity Index (CCI)[35]. Patients were considered to have these comorbidities if they had received a primary or secondary diagnosis for a condition at least twice during outpatient visits or once during hospitalization. CCI scores were calculated for all participants and categorized into four groups: 0, 1, 2, and ≥ 3. To determine disease severity, information was obtained on whether the patients were admitted to an ICU. Economic status was categorized into six levels depending on each patient's monthly income: ≤NT$20,008, NT$20,009–NT$28,800, NT$22,801–NT$36,300, NT$36,301–NT$45,800, and ≥ NT$45,801. The urbanization level of residential areas was divided into seven categories, with level 1 representing the most urbanized areas[36]. Additionally, healthcare organization characteristics, including hospital level (medical center, regional hospital, or district hospital) and organization type (public or nonpublic), were considered as part of the analysis.

Outcome measurement

The primary endpoint for this study was the risk of mortality within 30 days of admission. The secondary endpoints included hospital LOS, length of ICU stay, and the proportion of patients who required a 72-h ED revisit after discharge.

Statistical analysis

All statistical analyses were conducted using SAS software version 9.1 (SAS Institute, Cary, NC, USA). A p value less than 0.05 was considered statistically significant.

To minimize the potential effect of confounding factors between EDQIP group and non-EDQIP group or between pre-EDQIP group and EDQIP group, propensity score matching was performed using several variables, such as sex, age, monthly income, urbanization level, CCI score, hospital level, hospital type, and ICU admission status. The demographic data of patients with AIS are presented based on their grouping (pre-

EDQIP group, EDQIP group, and non-EDQIP group). Comparative analyses were conducted between the pre-EDQIP group and the EDQIP group after matching, as well as between the EDQIP group and the non-EDQIP group. Categorical variables are presented as numbers and percentages. An SMD ≤ 0.1 indicated no significant difference between the groups[37].

The 30-day mortality rate and 72-h ED revisit rate of the study participants are presented as crude case numbers and percentages. A log-rank test was conducted to explore differences in the cumulative survival probabilities of the participants. A multivariate analysis was conducted using a stratified Cox proportional-hazards regression model, with sex, age, monthly income, urbanization level, CCI score, hospital level, hospital type, and ICU admission status adjusted for. McNemar's test was used to evaluate differences in the 72-h ED revisit rate between the participants. To determine the effect of the EDQIP on the frequency of 72-h ED revisits, conditional logistic regression was applied. Hospital and ICU LOS were described using medians and interquartile ranges (IQR). Because the LOS data were not normally distributed, logarithmic transformations were applied for analysis. Wilcoxon's signed-rank test was used for bivariate analysis, followed by a multiple regression model with generalized estimating equations to account for the aforementioned covariates in multivariate analysis.

Since our study used the secondary dataset (Taiwan National Health Insurance Research Database, NHIRD), and the patient identifications in the NHIRD have been scrambled and de-identified by the Taiwan government for academic research use, informed consent was waived by the Research Ethics Committee. The research was conducted in accordance with the 1964 Declaration of Helsinki and its amendments and was approved by the institutional review board of Jen Ai Hospital (Institutional Review Board No. JAH 111 – 20), Taichung, Taiwan.

Data availability

The datasets for this study can be found in the National Health Insurance Research Database published by the Ministry of Health and Welfare (https:/www.mohw.gov.tw/np-108-2.html)).

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Author contributions
Y.J.C., Y.R.C., H.M.S., P.T.K., and W.C.T. participated in the study's design, discussed methodology, collected the data, and drafted the manuscript. W.C.T. and P.T.K. funded the study sources. Y.R.C. performed the data analysis, and Y.J.C. and Y.R.C. prepared all the tables and figures. All authors critically revised the report, commented on manuscript drafts, and approved the final report.

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Declarations

Competing interests
The authors have stated explicitly that there are no conflicts of interest in connection with this article.

Ethical approval
This study was approved by the research ethics committee of Jen Ai Hospital (Institutional Review Board No. JAH 111 – 20), Taichung, Taiwan.

Additional information
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