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Original Article

Efficacy of Emergency Room Skip Strategy in Patients Transferred for Mechanical Thrombectomy

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Objective: Time to recanalization is directly linked to cerebral infarction prognosis. However, patients transferred from another hospital take longer to arrive than those transported directly. To minimize time to recanalization, the emergency room (ER) skip strategy for hospital transfers was executed and reviewed.

Methods: From April 2019, patients transferred from another hospital for mechanical thrombectomy were carried into the angio-suite using emergency service stretchers. Results for these patients (ER skip group) were compared with those for patients transported directly to our hospital (Direct group).

Results: Among 108 cases in 32 months, 99 patients (91.7%) had major cerebral artery occlusion and underwent endovascular treatment. No differences in age, baseline National Institutes of Health Stroke Scale score, effective recanalization rate, or proportion of posterior circulation cases were seen between groups. The ER skip group (26 patients) showed significantly longer median time from onset to arrival (240 vs. 120 min; p = 0.0001) and significantly shorter median time from arrival to groin puncture (11 vs. 69 min; p = 0.0000). No significant differences were evident in time from groin puncture to recanalization (39 vs. 45 min), time from onset to recanalization (298 vs. 244 min), or rate of modified Rankin Scale score 0–2 after 90 days (42.3% vs. 32.9%). Median time from alarm to recanalization (266 vs. 176 min; p = 0.0001) was significantly longer in the ER skip group. Door-to-puncture (DTP) time for the Direct group gradually fell as the number of cases increased, reaching 40 min by the end of study period. In contrast, DTP time for the ER skip group remained extremely short and did not change further. The proportion of patients who underwent both CT and MRI before endovascular treatment was significantly lower in the Direct group (30.1%) than in the ER skip group (57.7%). In the ER skip group, median length of stay in the primary hospital was 119 min, and the median duration of interhospital transfer was 16 min.

Conclusion: The ER skip strategy for patients transferred with large vessel occlusion achieved favorable outcomes comparable to that for direct transport cases. Direct transport to a thrombectomy-capable stroke center remains ideal, however, because the time to intervention is improving for direct transport cases each year.

Keywords ▶ workflow, door-to-puncture time, time metric, mechanical thrombectomy, ischemic stroke

Introduction

Acute ischemic stroke due to large vessel occlusion (LVO) is a severe event with poor prognosis. Five randomized control trials reported in 2015 confirmed that mechanical thrombectomy (MT) improved the prognosis of LVO,[1–5] and the number of cases being treated in this manner has increased rapidly worldwide. Achieving high-quality recanalization of the occluded artery as soon as possible is fundamental to MT,[6–10] and a positive correlation exists between shorter recanalization time and higher quality recanalization; the earlier the intervention, the easier it is to obtain recanalization.[11]

On the other hand, facilities in which endovascular therapy (EVT) can be performed remain limited. Patients who develop acute stroke are often transported to the nearest hospital and then transferred to an EVT-capable facility if an intravenous recombinant tissue plasminogen activator (t-PA) or MT is indicated. Among MT

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cases, the proportion of patients transferred from other hospitals varies widely, from 7.4% to 61.3%, depending on the distribution of EVT-capable facilities and the regional system of emergency medical services.[12–14] Due to the door-in-to-door-out (DIDO) time of the initial hospital, transfer time, and additional tests at the EVT-capable facility, transfer cases must wait longer before starting treatment than directly transported cases. The time from onset to recanalization is reportedly delayed by an average of 100 min or more and the prognosis is poorer among patients transferred from another hospital compared to cases transported directly to an EVT-capable facility.[15]

Jadhav et al.[16] brought 111 cases transferred from another hospital directly into the angio-suite and compared the door-to-puncture (DTP) times and outcomes with those of 150 cases admitted via the emergency department. The significant reduction in DTP time for transferred cases resulted in similar prognosis for both groups. To minimize the time loss for patients transferred from other hospitals to our hospital, we have been skipping the emergency room (ER) and bringing all eligible patients directly to the angio-suite since April 2019. In parallel with this, various workflows have been reformed and optimized, such as altering the initial diagnostic imaging modality to CT and CTA instead of MRI for directly transported cases.[17] The aim of this study was therefore to clarify the time saved and clinical outcomes achieved using this ER skip protocol.

Materials and Methods

Data were extracted from a prospectively maintained, institutional review board-approved database. Subjects were consecutive patients with acute ischemic stroke with LVO who were transferred from another hospital to our hospital between April 2019 and November 2021 for the purpose of EVT (ER skip group). The comparative controls were consecutive patients with acute ischemic stroke from LVO within 6 h of onset who were transported directly to our hospital during the same period and underwent EVT (Direct group). Cases with in-hospital onset were excluded.

Based on the Japanese stroke guideline 2017, patients with LVO confirmed by CTA or MRA with National Institutes Health Stroke Scale (NIHSS) score ≥4 and Alberta Stroke Program Early CT Score (ASPECTS) ≥6 with penumbra presumed to remain were included. Recording the onset or last known well time (onset), recognition of abnormal status time by bystanders (alarm), our hospital arrival time (door), diagnostic imaging time (picture), groin puncture time (puncture), and final recanalization time (recanalization), the following time metrics were extracted: onset-to-door (OTD) time, alarm-to-door (ATD) time, door-to-image (DTI) time, DTP time, puncture-to-recanalization (PTR) time, door-to-recanalization (DTR) time, onset-to-recanalization (OTR) time, and alarm-to-recanalization (ATR) time. In transfer cases, recording primary hospital arrival time (door-in) and primary hospital departure time (door-out), the following time metrics were also extracted: OTD-in time, ATD-in time, and DIDO time. In addition, the following basic information was collected: age, sex, underlying illness, histories of drinking and smoking, pre-stroke modified Rankin Scale (mRS) score, baseline NIHSS, ASPECTS, occlusion site, brain imaging modalities before catheter cerebral angiography, and use of intravenous t-PA. The ASPECTS of transferred cases was determined based on CT images taken at the referring hospitals. Endovascular procedures were performed under local anesthesia in all cases, with mild sedation used as needed. The presence of LVO was confirmed by catheter angiography. When LVO was not found in the target vessel by catheter angiography, after confirming by 3D rotational angiography, the patient was switched to conservative treatment while reconfirming the neurological symptoms. Cases in which LVO was observed and EVT was performed were added to the analysis. In anterior circulation cases, 9-Fr balloon guiding catheters were used in all cases, and in principle, MT was performed using a combined method with a stent retriever and an aspiration catheter. If vessel occlusion remained after the first pass, repeated thrombectomy, direct aspiration, percutaneous transluminal angioplasty, or carotid artery stenting with loading of dual antiplatelet agents was performed at the discretion of the operator.

The following information during and after treatment were collected: MT method, number of passes, quality of recanalization (modified thrombolysis in cerebral infarction [mTICI] score), symptomatic intracranial hemorrhage (intraparenchymal hemorrhage that appeared within 24 h after treatment and >30% of the cerebral infarct area as defined in European Cooperative Acute Stroke Study II criteria type 2,[18]) death, and mRS score after 90 days.

ER skip protocol

Prior to the transfer of LVO patients, we were contacted in advance by telephone by doctors from the referring hospitals. Transferred patients were passed through the ER and carried directly into the angio-suite on an emergency medical service stretcher without additional imaging. If the cerebral angio-suite was unavailable, the patient was carried into the adjacent cardiac angio-suite. The distance from the entrance of the ER to the cerebral angio-suite was 98 m. On the way to the angio-suite, neurological symptoms were confirmed, and some additional information was obtained from the referring doctor who had accompanied the patient in the ambulance. Preparations for EVT such as perfusion route and heparin saline were started at the time of call for transfer, and a neuro-interventionalist, nurses, and radiologists were waiting in the angio-suite. As soon as the patient was transferred to the angio table, preparations for groin puncture began. At the same time, written informed consent for both EVT and the ER skip protocol was obtained from the family of the patient. Cone-beam CT with a flat panel detector was not performed before treatment unless significant deterioration of neurological symptoms was seen during transfer. A blood sample was submitted after the sheath introducer was inserted, and a chest X-ray and electrocardiogram were obtained after completing EVT.

Statistical analysis

IBM SPSS version 19 (IBM, Armonk, NY, USA) was used for all statistical analyses. Standard descriptive statistics were used, with median and interquartile range (IQR) for continuous variables. Mean and standard deviation were used for the frequency distribution of categorical variables. In comparisons between two groups, Mann–Whitney's rank sum test was used for continuous variables, and the chi-square test and Fisher's exact test were used for categorical variables. Values of $p < 0.05$ were judged to be significant for the two-sided probability.

Results

Twenty-nine cases were urgently transferred from another hospital to our hospital within the 32-month study period, of which 26 cases with LVO confirmed by catheter angiography were treated using EVT. During that same period, 79 cases were directly transported to our hospital and underwent emergency catheter angiography, of which 73 cases with LVO were treated with EVT.

Baseline characteristics, time metrics, and treatment result for each group are shown in **Table 1**. No significant differences between groups were seen for age, sex, risk factors (underlying conditions, smoking and drinking habits, history of stroke, oral antithrombotic drugs), pre-stroke mRS score, ASPECTS, baseline NIHSS, site of vessel occlusion, or rate of posterior circulation.

LVO was confirmed by CTA or MRA in 24 cases (92.3%) in the ER skip group and in 71 cases (97.2%) in the Direct group. Prior to catheter angiography, performance of both CT and MRI was less frequent in the Direct group (30.1%) than in the ER skip group (57.7%).

OTD (240 vs. 120 min) and ATD (194 vs. 60 min) were significantly longer in the ER skip group than in the Direct group, respectively. On the other hand, DTI (5 vs. 18 min) and DTP (11 vs. 69 min) were significantly shorter in the ER skip group than in the Direct group. However, in the ER skip group, cone-beam CT before catheter angiography was taken only in the first three cases. As the results did not affect the decision to perform catheter angiography, this modality was not performed in the subsequent cases. No significant difference in PTR (39 vs. 45 min) was evident between groups. DTR (52 vs. 125 min) was significantly shorter in the ER skip group than in the Direct group. OTR (298 vs. 244 min) tended to be longer in the ER skip group but did not differ significantly from that in the Direct group. However, ATR (266 vs. 176 min) was significantly longer in the ER skip group (**Fig. 1**). OTD-in time (92 min) in the ER skip group was not significantly different from OTD in the Direct group (120 min; $p = 0.3173$). Similarly, ATD-in time (48 min) in the ER skip group was not significantly different from ATD time in the Direct group (60 min; $p = 0.3472$). DIDO of the ER skip group was 119 min and interhospital transfer time was 16 min. Median interhospital transfer time depended on the transfer distance. Fourteen minutes (IQR, 12–17 min) was required for 20 cases from the two referring hospitals (including one primary stroke center) in the same city as our hospital, but a significantly longer time (51.5 min; IQR 48–52 min) was required for 6 cases from the two referring hospitals outside the city ($p < 0.01$).

All intravenous t-PA therapies performed in the ER skip group were initiated at the primary hospital and transferred using a drip-and-ship method. No difference between groups was identified in the usage of intravenous t-PA or the combined method with a stent retriever and an aspiration catheter. Likewise, no differences were seen between the two groups in the rate of complete recanalization on the first pass, final substantial recanalization (mTICI 2b-3), or postoperative symptomatic parenchymal hemorrhage. No significant difference in the mRS score after 90 days was

Table 1 Study cohort, time metrics, and outcomes

	Overall	ER skip	Direct	p value	Note
Demographic characteristics					
n of patients, (%)	99 (100)	26 (26.3)	73 (73.7)		
Age, median (IQR)	81 (77–86)	84 (79–88)	80 (74–85)	0.0629	ns
Age ≥85, n (%)	36 (36.4)	12 (46.1)	24 (32.9)	0.1556	ns
Female, n (%)	49 (49.5)	10 (38.5)	39 (53.4)	0.2541	ns
Risk factors, n(%)					
Hypertension	78 (78.8)	24 (92.3)	54 (74.0)	0.0550	ns
Diabetes mellitus	15 (15.2)	5 (19.2)	10 (13.7)	0.0531	ns
Hyperlipidemia	29 (29.3)	6 (23.1)	23 (31.5)	0.4639	ns
Atrial fibrillation	60 (60.6)	18 (69.2)	42 (57.5)	0.3545	ns
Smoking habit	30 (30.3)	8 (30.8)	22 (30.1)	1.0000	ns
Drinking habit	38 (38.4)	14 (53.8)	24 (32.9)	0.0658	ns
Previous stroke	27 (27.3)	7 (26.9)	20 (27.4)	1.0000	ns
Antiplatelet	17 (17.2)	3 (11.5)	14 (19.2)	0.5472	ns
Anticoagulant	34 (34.3)	11 (42.3)	23 (31.5)	0.3439	ns
Scores at admission					
Prestroke mRS score ≥3, n (%)	15 (15.2)	2 (7.7)	13 (17.8)	0.3412	ns
ASPECTS, median (IQR)	10 (9–10)	10 (8–10)	10 (9–10)	0.9283	ns
NIHSS score on admission, median (IQR)	23 (18–29)	20 (18–28)	23 (18–29)	0.3321	ns
Brain imaging modalities before catheter angiography, n (%)					
CT	4 (4.0)	2 (7.7)	2 (2.7)	0.2813	ns
MRI/A	7 (7.1)	4 (15.4)	3 (4.1)	0.0752	ns
CT/A	51 (51.5)	5 (19.2)	46 (63.0)	0.0002	†
CT, MRI/A	30 (30.3)	13 (50.0)	17 (23.3)	0.0143	*
CT/A, MRI/A	7 (7.1)	2 (7.7)	5 (6.8)	1.0000	ns
Occlusion site, n (%)					
ICA	28 (28.3)	8 (30.8)	20 (27.4)	0.8017	ns
M1	38 (38.4)	8 (30.8)	30 (41.1)	0.4818	ns
M2–M3	20 (20.2)	7 (26.9)	13 (17.8)	0.3946	ns
A2–A3	2 (2.0)	1 (3.8)	1 (1.4)	0.4583	ns
BA	6 (6.1)	1 (3.8)	5 (6.8)	1.0000	ns
Multiple	5 (5.1)	1 (3.8)	4 (5.5)	1.0000	ns
Time metrics (min), median (IQR)					
OTD	150 (70–265)	240 (178–364)	120 (59–219)	0.0001	†
ATD	70 (45–163)	194 (166–243)	60 (40–79)	0.0001	†
DTI	17 (12–23)	5 (4–13)	18 (12–24)	0.0285	*
DTP	53 (16–83)	11 (10–13)	69 (51–100)	0.0000	†
PTR	44 (30–66)	39 (31–54)	45 (29–70)	0.4654	ns
DTR	105 (66–148)	52 (42–67)	125 (90–165)	0.0000	†
OTR	260 (188–372)	298 (229–418)	244 (172–372)	0.0949	ns
ATR	199 (158–267)	266 (209–294)	176 (147–244)	0.0006	†
OTD-in		92 (44–202)			
ATD–in		48 (39–65)			
DIDO		119 (89–144)			
Door-out-to-door (interhospital transfer)		16 (12–26)			
Reperfusion treatment, n (%)					
IV-t-PA	35 (35.4)	13 (50.0)	22 (30.1)	0.4887	ns
Combined MT	66 (67.7)	14 (53.8)	52 (71.2)	0.1458	ns
First pass effect (1pass mTICI 2c-3)	36 (36.4)	11 (42.3)	25 (34.2)	0.4846	ns
Substantial reperfusion (mTICI 2b-3)	78 (78.8)	22 (84.6)	56 (76.7)	0.5775	ns
Symptomatic parenchymal hemorrhage	3 (3.0)	1 (3.8)	2 (2.7)	1.0000	ns
Outcome at 90 days, n (%)					
mRS score 0–2	35 (35.4)	11 (42.3)	24 (32.9)	0.4749	ns

(Continued)

Table 1 (Continued)

	Overall	ER skip	Direct	p value	Note
mRS score 0–3	42 (42.4)	13 (50.0)	29 (39.7)	0.4887	ns
#corrected mRS score 0–2	30 (50.8)	9 (64.3)	21 (46.7)	0.3604	ns
Death	18 (18.2)	4 (15.4)	14 (19.2)	0.7743	ns

Data are displayed as median (IQR) or percentage (n/N). *p <0.05, †p <0.01, #excluding patients ≥ 85 years old and with pre-stroke mRS score ≥3. A2–A3: the second or third segment of the anterior cerebral artery; ASPECTS: Alberta stroke program early CT score; ATD: alarm-to-door; ATR: alarm-to-recanalization; BA: basilar artery; CT/A: CT and CTA; DIDO: door-in-to-door-out; DTI: door-to-image; DTP: door-to-puncture; DTR: door-to-recanalization; ER: emergency room; ICA: internal carotid artery; IQR: interquartile range; IV-t-PA: intravenous tissue plasminogen activator; M1: the first segment of the middle cerebral artery; M2–M3: the second or third segment of the middle cerebral artery; MRI/A: MRI and MRA; mRS: modified Rankin Scale; MT: mechanical thrombectomy; mTICI: modified thrombolysis in cerebral infarction; NIHSS: National Institutes of Health Stroke Scale; ns: not significant; OTD: onset-to-door; OTR: onset-to-recanalization

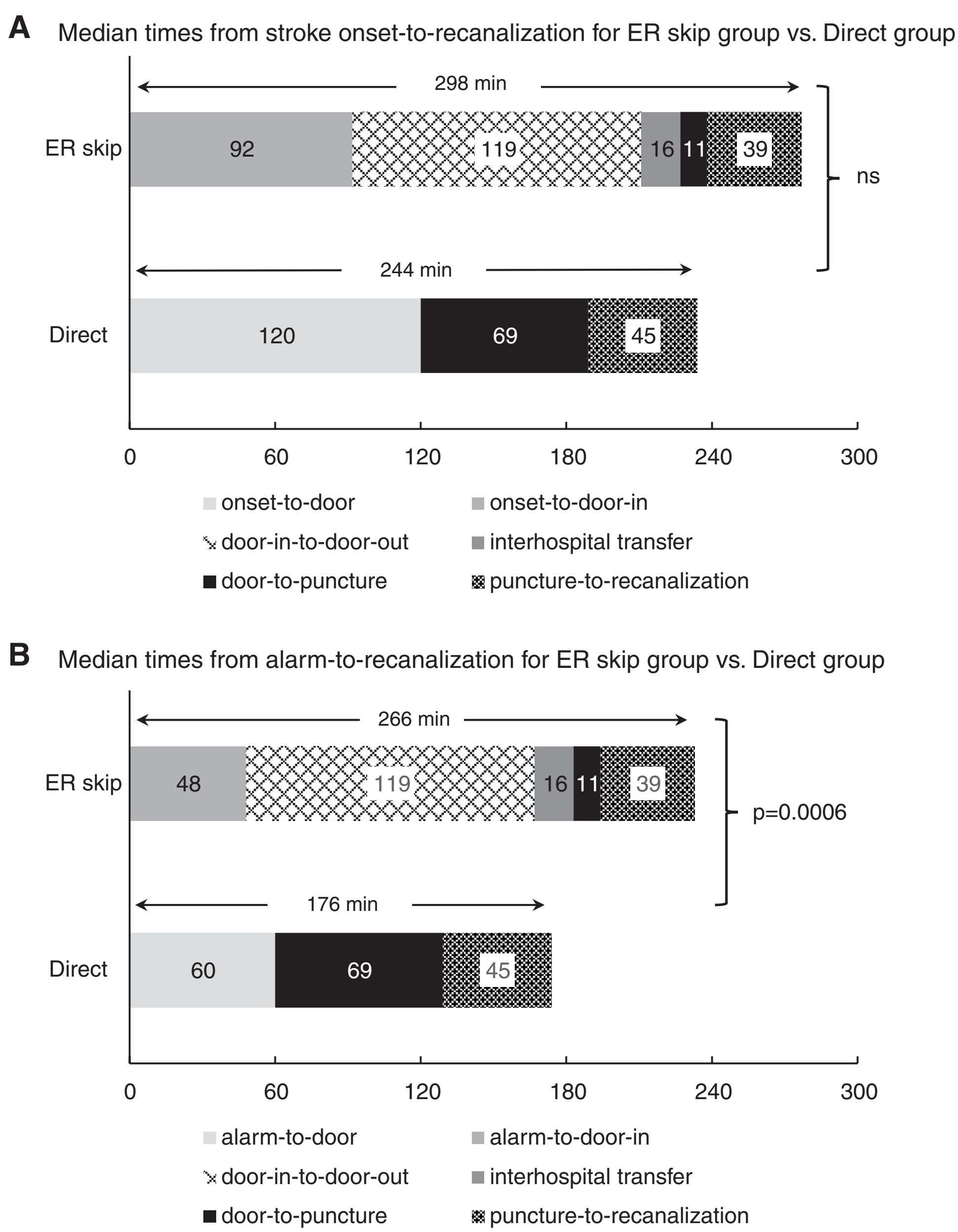

Fig. 1 Median intervals to recanalization from (**A**) stroke onset (time of last known well) and (**B**) alarm (recognition of abnormal status by bystanders). Significant differences are seen in OTD time, DTP time, ATD time, and ATR time between the ER skip group and the Direct group. ATD: alarm-to-door; ATR: alarm-to-recanalization; DTP: door-to-puncture; ER: emergency room; ns: not significant; OTD: onset-to-door

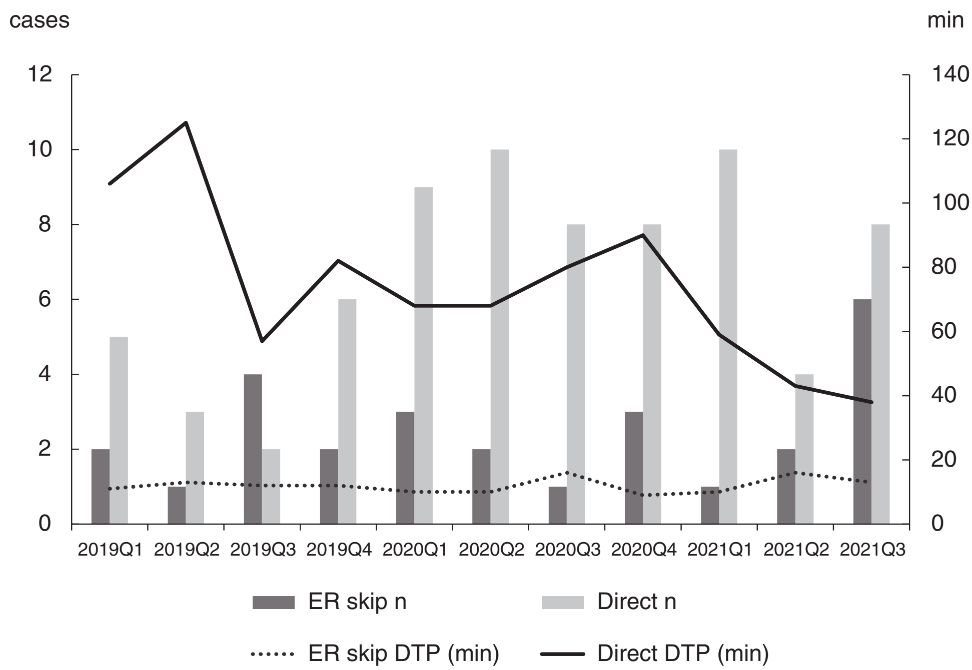

Fig. 2 Changes in the number of cases and median DTP time every quarter of the fiscal year (starting from April). DTP: door-to-puncture; ER: emergency room; Q: quarter

seen between groups. Even excluding cases of super-elderly individuals ≥85 years old and cases with pre-stroke mRS score ≥3, prognosis after 90 days did not differ between the ER skip group and the Direct group.

Figure 2 shows the quarterly number of cases and DTP in the ER skip group and in the Direct group. DTP for the Direct group gradually fell as the number of cases increased, reaching 40 min by the third quarter of fiscal 2021 (starting from April 2021). DTP for the ER skip group remained extremely short and did not change further.

Discussion

Given that longer OTR is strongly associated with worse prognosis, urgent EVT should be provided to patients transferred from other hospitals. In this study, the OTD for the transferred cases was delayed by 120 min compared to directly transported cases, but DTP could be shortened by up to 58 min by skipping the ER. As a result, the delay in OTR for the ER skip group was shortened to 54 min, with no significant difference between groups. No difference in the proportion of good outcomes after 3 months was seen between groups. However, the time loss due to passing through the previous hospital had a large impact of 90 min on ATR, which was significantly delayed in the ER skip group.

A method called direct transfer to the angio-suite (DTAS) was first reported in 2017.[19–22] Our ER skip strategy and direct access to the angio-suite were performed only for transferred patients, so the method is similar, but the subject differs from DTAS. DTAS is a method for bringing a stroke patient to the angio-suite under conditions of uncertainty regarding whether cerebral infarction or intracerebral hemorrhage is present, with progression to catheter angiography as soon as cone-beam CT rules out hemorrhagic disease in the patient. Some reports have found that DTAS brings about better prognosis due to the shortened DTP,[23] whereas other reports have described the prognosis as the same as a normal pathway from CT to the angio-suite.[24] To perform DTAS, obtaining sufficient image quality with the latest cone-beam CT is desirable.[25] The flat-panel systems currently used in Japan can exclude hemorrhagic disease but are still far from the image quality of multi-slice CT for the detection of early CT signs. Moreover, the number of comprehensive stroke centers possessing two or more cerebral angio-suites that are always available remains limited in Japan. Furthermore, considering that the rate of intracerebral hemorrhage is much higher in Japan than in Western countries, it would be inefficient and thus is still uncommon to perform DTAS for all stroke patients, and more manpower would be required to achieve this. At present, we consider that CT should be performed and the results brought into the angio-suite in cases of direct transport. Not returning to the ER after CT is the most important for shortening the DTP. The ER skip group in this report had been diagnosed with LVO at the referring hospital, and we had already finished preparation for EVT by the time the patient arrived. For this reason, DTP in our ER skip group (11 min) was shorter than that reported in any other DTAS paper and is the shortest yet reported.

The ER skip strategy does not require the introduction of new hardware or software. Further, this method has the advantage of being executable at any facility at any time simply by changing the protocol followed by medical staff. We have encountered many cases with the dramatic improvement of symptoms using this treatment, and as a result of the change in protocol in the hospital and the commitment of the team, the DTP in direct transport cases is falling year by year. In American Heart Association (AHA) Target Stroke Phase III,[26] 1) door-to-device time within 90 min for direct transport cases and 2) door-to-device time within 60 min for transfer cases are recommended in more than half of cases. We achieved both time goals with the introduction of the ER skip strategy. In addition, we established a calling system in November 2021 by which the local ambulance crew can contact the neuro-interventionalist directly when LVO is suspected. DTP is expected to be further reduced in this way.

Onset is set as the time of last known well in some cases and so represents only a weak guide for finding ways to make improvements in time saved. The time from awareness of an abnormal status by family members of the patient or bystanders to hospital arrival offers a more noteworthy indicator for ways to improve workflow.[15] If the emergency medical service takes the patient to the nearest hospital, arrival time at the primary hospital would be shorter. However, in the case of LVO, this reduction in time is offset by the interhospital transfer. Choi et al.[27] reported that a DIDO time <60 min was ideal and achievable when transferring LVO patients from a primary stroke center to a comprehensive stroke center. To reduce DIDO to 60 min, brain imaging modalities should be limited to one, and intravenous t-PA therapy should be started promptly using the drip-and-ship approach. Although not implemented in our area, neuro-interventionalists at thrombectomy-capable centers should be able to make quicker, more accurate decisions if remote access can be given to the primary stroke center picture archiving and communication system database via a secure website. As a simpler method, the ambulance transporting the patient can be kept waiting at a primary hospital until a diagnosis is made.[28] In the future, delays to ATR in transferred cases as compared to directly transported cases will increase unless considerable changes in the protocols of primary stroke centers are obtained. Although no significant difference was apparent, the prognosis tended to be better for the ER skip group, which showed a long OTR time in this study. This is because low ASPECTS-diffusion-weighted image (DWI) cases may have been excluded by the performance of both CT and MRI at the referring hospital, and direct transport cases tend to be treated more aggressively. Eventually, even if the ER skip strategy is executed for transferred cases, the same prognosis is unlikely to be secured as compared with direct transport cases.

It should be noted that this study offers an analysis of a relatively small cohort from a single center and needs to be verified by a prospective multicenter study with a larger population. Moreover, treating all stroke patients in thrombectomy-capable stroke centers or comprehensive stroke centers instead of primary stroke centers is difficult due to limitations on hospitalizations and personnel resources. As a limitation to the ER skip strategy, if an image transmission system has not been constructed, the neuro-interventionalist will often confirm images from the primary hospital after groin puncture. The treatment indication therefore largely depends on the diagnosis of the referring doctor. In this series, no major discrepancies in diagnoses or indications were seen for transfer cases because the doctors at the referring hospital were neurosurgeons or neurologists. Also, since our hospital is the only thrombectomy-capable stroke center in the secondary medical service area, a great advantage of the area is that doctors in the primary hospitals do not have to worry about the transfer destination, even if the transportation distance is long. This point is very different from that of metropolitan areas, so caution is required in generalizing the results of this study.

Pre-hospital stroke scales such as the emergent large vessel occlusion (ELVO) screen[29] that sharply distinguish LVO from other pathologies should be promoted in local areas.[30] Appropriate patients for MT should be selectively and directly transported to thrombectomy-capable stroke centers or comprehensive stroke centers by emergency medical services.

Conclusion

The ER skip strategy for patients with LVO transferred to a thrombectomy-capable stroke center achieved shortening of DTP and favorable outcomes equivalent to that for directly transported cases. Direct transport to a thrombectomy-capable stroke center remains ideal, however, because the time to intervention is improving for direct transport cases each year.

Disclosure Statement

The authors declare that they have no conflicts of interest.

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