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Original Article

CT- versus MRI-Based Imaging for Thrombolysis and Mechanical Thrombectomy in Ischemic Stroke: Analysis from the Austrian Stroke Registry

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Background and Purpose It is unclear whether a particular stroke imaging modality offers an advantage for the acute stroke treatment. The aim of this study was to compare procedure times, efficacy and safety of thrombolysis and/or thrombectomy based on computed tomography (CT) versus magnetic resonance imaging (MRI) acute stroke imaging.

Methods Data of stroke patients who received intravenous thrombolysis (IVT) and/or mechanical thrombectomy (MT) were extracted from a nationwide, prospective stroke unit registry and categorized according to initial imaging modality. Study endpoints included procedure times, symptomatic intracerebral hemorrhage (sICH), early neurological improvement, 3-month functional outcome by modified Rankin Scale (mRS) and mortality.

Results Stroke patients (n=16,799) treated with IVT and 2,248 treated with MT were included. MRI-guided patients (n=2,599) were younger, had less comorbidities and higher rates of strokes with unknown onset as compared to CT-guided patients. In patients treated with IVT, no differences were observed regarding the rates of functional outcome by mRS 0–1 (adjusted odds ratio [OR], 0.87; 95% confidence interval [CI], 0.71 to 1.05), sICH (adjusted OR, 0.82; 95% CI, 0.61 to 1.08), and mortality (adjusted OR, 0.88; 95% CI, 0.63 to 1.22). Patients undergoing MT selected by MRI as compared to CT showed equal rates of functional outcome by mRS 0–2 (adjusted OR, 0.87; 95% CI, 0.65 to 1.16), sICH (adjusted OR, 0.9; 95% CI, 0.51 to 1.69), and mortality (adjusted OR, 0.62; 95% CI, 0.35 to 1.09). MRI-guided patients showed a significant intrahospital delay of about 20 minutes in both the IVT and the MT group.

Conclusions This large non-randomized comparison study indicates that CT- and MRI-guided patient selection for IVT/MT may perform equally well in terms of functional outcome and safety.

Keywords Computed tomography; Magnetic resonance imaging; Thrombectomy; Thrombolysis; Outcome

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Introduction

In patients with suspected acute ischemic stroke neuroimaging is essential to confirm the diagnosis and identify candidates for recanalization treatments. Computed tomography (CT) is the most common imaging used in the acute phase. This modality is easy to perform, fast and widely available. Magnetic resonance imaging (MRI) is more sensitive to detect early ischemic changes;[1] however, it is eventually more time consuming and definitely less widely available. On the other hand, some studies suggested lower rates of symptomatic intracerebral hemorrhage (sICH) after intravenous thrombolysis (IVT)[2] in MRI-guided patients and studies investigating imaging in late time window (>4.5 hours) or wake up stroke (WUS) setting tended to show superiority of MRI.[3] In patients undergoing mechanical thrombectomy (MT), CT-guided indication seemed to be associated with futile outcome more frequently.[4] However, in the mechanical thrombectomy after intravenous alteplase versus alteplase alone after stroke (THRACE) study the choice of imaging was not associated with functional outcome in patients treated with MT.[5] Thus, we aimed to examine the relevance of initial imaging modality on procedure times, safety and functional outcome in patients undergoing IVT and/or MT in a large nationwide prospective stroke registry.

Methods

The Austrian Stroke Unit Registry (ASUR) is a nationwide prospective registry of the Austrian stroke unit network currently encompassing 39 stroke units, founded by the Federal Ministry of Health (Appendix 1). Data collected between 2003 and 2020 were included for IVT treatment and MT data were enrolled between 2013 and 2020. Methodological details have been published previously.[6] Anonymized data on admission, discharge and at 3 months follow-up are registered for all patients admitted with acute ischemic stroke. Three months follow was performed in person or by telephone call. Baseline characteristics, risk factors, acute treatment, and functional outcome are assessed in this web-based database. The registry is supervised and granted by an academic review board and is part of the quality assessment in stroke care. Individual informed consent was not obtained.

For the purposes of the current study, following variables were extracted from the registry: age, sex, IVT treatment, endovascular treatment, National Institutes of Health Stroke Scale (NIHSS) at admission and discharge from stroke unit, modified Rankin Scale (mRS)—pre-stroke, at discharge and at 3 months follow-up, risk factors (hypertension, diabetes, hypercholesterolemia, smoking, previous stroke, atrial fibrillation, coronary heart disease, and peripheral artery disease), WUS, onset to door time (ODT), onset to treatment time (OTT), door to needle time (DNT), and sICH according to European Cooperative Acute Stroke Study (ECASS) 3 criteria.[7] Patients undergoing IVT and/or MT were primarily grouped according to initial stroke imaging using CT or MRI. Following study endpoints have been defined:

(1) Safety endpoint: sICH according to ECASS 3 criteria
(2) Efficacy endpoints for IVT: NIHSS improvement ≥4 between admission and discharge from stroke unit, mRS at 3 months 0–1 and mortality at 3 months
(3) Efficacy endpoints for MT: NIHSS improvement ≥8 between admission and discharge from stroke unit, mRS at 3 months 0–2 and mortality at 3 months
(4) Procedure endpoints: DNT and OTT

Statistics

Results are presented as median, range, and interquartile range for continuous variables, while categorical variables are summarized by absolute x (n) and relative (%) frequencies. Patients were categorized into groups based on CT- or MRI-guided and treatment by IVT/MT. Mann-Whitney U test was used to compare the locations of continuous and ordinal variables without a normal distribution. Pearson's chi-square test was comparing frequency and distribution of categorical variables. Multivariable logistic regression models were applied to adjust for baseline imbalances in the variables, explaining the outcome by age, sex, stroke syndrome, stroke severity (NIHSS), pre-stroke mRS, and vascular risk factors including hypertension, diabetes, hypercholesterolemia, smoking, previous stroke, atrial fibrillation, coronary heart disease, and peripheral artery disease. The effect of multiple testing has been adjusted by applying Bonferroni correction. All statistics were performed using statistical software R version 3.0.1 (R Foundation for Statistical Computing, Vienna, Austria).

Ethics

The study was approved by the local ethics committee. As a part of routine observational quality registry, patient consent for registration was not required by Austrian legislation.

Results

Safety and efficacy of CT- versus MRI-guided thrombolysis

From 140,710 patient files in ASUR, 16,799 patients treated with IVT and/or MT had complete datasets and entered the

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analysis. Of those, 2,226 (13.3%) underwent initial MRI and 14,573 (86.7%) initial CT imaging. Three months follow-up data were present for 6,756 (40.2%) patients. Baseline characteristics did not differ to the lost to follow-up group (data not shown). Baseline characteristics of the MRI and CT subgroups showed significant difference in age, risk factors, and stroke severity (Table 1). MRI-guided stroke patients were younger (median 72 years vs. 75 years, P<0.001), had lower frequencies of risk factors and presented with less severe strokes (median NIHSS 6 vs. 8, P<0.001). DNT was significantly shorter in CT-guided patients with a difference of approximately 20 minutes (45 minutes vs. 62 minutes, P<0.001). Wake up strokes were significantly more frequent in the MRI group as compared to the CT group (646 [29.0%] vs. 1,412 [9.7%], P<0.001).

In order to adjust for the baseline imbalances between the CT and MRI groups, we further calculated multivariable regression models entering MRI-guided therapy as a covariate to and IVT/MT safety and efficacy endpoints as the response. After adjustment for age, gender, admission NIHSS, pre-stroke mRS, hypertension, diabetes, previous stroke, hypercholesterinemia, myocardial infarction, atrial fibrillation, coronary artery disease, peripheral artery disease, smoking, sICH, ODT, OTT, and DNT, MRI-guided IVT as compared to CT-guided IVT was not associated with sICH (adjusted odds ratio [OR], 0.82; 95% confidence interval [CI], 0.61 to 1.08), neurological improvement NIHSS ≥4 (adjusted OR, 1.09; 95% CI, 0.98 to 1.22), functional outcome mRS 0–1 at 3 months (adjusted OR, 0.86; 95% CI, 0.7 to 1.05), or mortality (adjusted OR, 0.88; 95% CI, 0.63 to 1.22).

Table 1. Comparison of baseline characteristics of CT- and MRI-guided patients treated with IVT only

Characteristic	CT (n=14,573, 86.7%)	MRI (n=2,226, 13.3%)	P
WUS/SUO	1,412 (9.7)	646 (29.0)	<0.001
Age (yr)	75 (65–83)	72 (62–81)	<0.001
Female sex	6,932 (47.7)	1,034 (46.5)	0.326
Admission NIHSS	8 (5–15)	6 (3–11)	<0.001
Pre-stroke mRS 0–1	11,951 (82.6)	1,884 (84.8)	0.130
Hypertension	11,420 (79.5)	1,699 (76.9)	0.015
Diabetes mellitus	2,991 (20.8)	520 (23.6)	0.009
Previous stroke	2,594 (18.1)	402 (18.2)	<0.001
Myocardial infarction	1,319 (9.2)	179 (8.1)	<0.001
Hypercholesterolemia	7,624 (53.1)	1,166 (52.8)	0.091
Atrial fibrillation	4,273 (29.8)	568 (25.7)	0.003
Coronary artery disease	3,046 (21.2)	431 (19.5)	0.075
Peripheral artery disease	771 (5.4)	127 (5.8)	0.034
Smoking	2,236 (15.6)	462 (20.9)	<0.001
sICH	588 (4.0)	61 (2.8)	0.005
Improvement NIHSS ≥4	6,049 (44.5)	828 (38.9)	<0.001
mRS at 3 months 0–1	2,415 (16.6)	429 (19.3)	0.002
ODT (min)	74 (50–110)	78 (50–126)	<0.001
DNT (min)	45 (30–65)	62 (45–86)	<0.001
OTT (min)	120 (90–165)	150 (110–205)	<0.001

Values are presented as number (%) or median (interquartile range).
CT, computed tomography; MRI, magnetic resonance imaging; IVT, intravenous thrombolysis; WUS, wake up stroke; SUO, unknown onset stroke; NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; sICH, symptomatic intracerebral hemorrhage; ODT, onset to door time; DNT, door to needle time; OTT, onset to treatment time.

Safety and efficacy of CT- versus MRI-guided thrombolysis in WUS/unknown onset stroke

WUS/unknown onset stroke (SUO) was present in 2,058 cases (12.2%). Six hundred forty-six WUS/SUO received MRI and 1,412 WUS/SUO stroke patients received CT imaging. The rates of WUS/SUO were significantly higher in the MRI-guided group as compared to CT-guided group (29% vs. 9.7%, P<0.001). Age (mean 74 years vs. 76 years, P<0.001), admission NIHSS (median 7 vs. 9, P<0.001), and pre-stroke mRS 0 (70.6% vs 66.2%, P=0.052) showed significant differences between the MRI and

Table 2. Comparison of baseline characteristics of CT- and MRI-guided WUS/SUO patients treated with IVT only

Characteristic	CT-guided (n=1,412)	MRI-guided (n=646)	P
Age (yr)	76 (66–84)	74 (64–82)	<0.001
Female sex	677 (47.9)	307 (47.5)	0.859
Admission NIHSS	9 (5–16)	7 (4–12)	<0.001
Pre-stroke mRS 0–1	1,091 (77.8)	538 (83.3)	0.052
Hypertension	1,137 (81.5)	510 (79.6)	0.542
Diabetes mellitus	291 (20.9)	159 (24.8)	0.124
Previous stroke	234 (16.8)	125 (19.5)	0.194
Myocardial infarction	131 (9.4)	53 (8.3)	0.195
Hypercholesterolemia	746 (53.5)	339 (52.9)	0.887
Atrial fibrillation	450 (32.3)	172 (26.8)	0.083
Coronary artery disease	281 (20.2)	122 (19.0)	0.820
Peripheral artery disease	88 (63.2)	39 (6.1)	0.129
Smoking	202 (14.5)	122 (19.0)	0.001
sICH	62 (4.4)	21 (3.3)	0.236
Improvement NIHSS ≥4	551 (42.1)	208 (34.1)	<0.001
MRS at 3 months 0–1	188 (13.3)	112 (17.3)	0.016
DNT (min)	47 (30–75)	60 (45–83)	<0.001

Values are presented as median (interquartile range) or number (%).
CT, computed tomography; MRI, magnetic resonance imaging; WUS, wake up stroke; SUO, unknown onset stroke; IVT, intravenous thrombolysis; NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; sICH, symptomatic intracerebral hemorrhage; DNT, door to needle time.

CT group (Table 2). There was a significant time delay in DNT of 13 minutes (median DNT 60 minutes vs. 47 minutes, *P*<0.001) in the MRI-guided group. CT-guided patients had higher rates of neurological improvement NIHSS ≥4 (551 [42.1%] vs. 208 [34.1%], *P*<0.001) and better functional outcome mRS 0–1 (138 [21.4%] vs. 237 [16.8%], *P*=0.013) in the univariate analysis. The rate of sICH did not differ significantly (21 [3.3%] vs. 62 [4.4%], *P*=0.236). After adjustment, MRI-guided thrombolysis was not associated with higher rates of neurological improvement NIHSS ≥4 (adjusted OR, 0.91; 95% CI, 0.72 to 1.15), nor with better functional outcome mRS 0–1 (adjusted OR, 0.84; 95% CI, 0.67 to 1.04), showed equal rates of sICH (adjusted OR, 0.83; 95% CI, 0.49 to 1.4), and mortality at 3 months follow-up (adjusted OR, 1.08; 95% CI, 0.59 to 1.97).

Safety and efficacy of CT- versus MRI-guided MT

Patients (n=2,249) underwent MT, MRI-guided 373 (16.6%) and CT-guided 1,876 (83.4%). CT-guided patients treated with MT were significantly older (mean 73 years vs. 71 years, *P*<0.001), and had higher NIHSS on admission (median 16 vs. 14, *P*<0.001) (Table 3). However, there were no significant differences in comorbidities, risk factors, pre-stroke mRS, or IVT administration (Table 3). MRI-guided patients showed a significant delay in time to treatment of 20 minutes (median DNT 124 minutes vs. 105 minutes, *P*<0.001). Both groups did not differ significantly in neurological improvement NIHSS ≥8 (669 [38.9%] vs. 112 [31.4%], *P*=0.008). Functional outcome at 3 months expressed by dichotomized mRS 0–2 was achieved in 623 (33.2%) vs. 148 (39.7%), *P*=0.016, favoring MRI-guided patients. sICH occurred in 14 (3.8%) vs. 9 (4.9%) and the difference was not statistically significant (*P*=0.36). Mortality at 3 months was significantly higher in the CT-guided group (389 [23.4%] vs. 56 [17%], *P*<0.001). After adjustment, MRI-guided MT was not associated with higher rates of neurological improvement NIHSS ≥8 (adjusted OR, 1.16; 95% CI, 0.82 to 1.62), occurrence of sICH (adjusted OR, 0.92; 95% CI, 0.51 to 1.69), functional neurological outcome mRS 0–2 (adjusted OR, 0.87; 95% CI, 0.65–1.16), or mortality (adjusted OR, 0.62; 95% CI, 0.35 to 1.09).

Table 3. Comparison of baseline characteristics of CT- and MRI-guided patients treated with mechanical thrombectomy

Characteristic	CT-guided (n=1,876, 83.4%)	MRI-guided (n=373, 16.6%)	*P*
WUS	404 (71.3)	159 (28.2)	<0.001
Age (yr)	73 (62–80)	71 (58–78)	<0.001
Female sex	918 (48.9)	198 (53.1)	0.143
Admission NIHSS	16 (12–20)	14 (9–19)	<0.001
Pre-stroke mRS 0–1	1,669 (89.1)	337 (90.7)	0.543
Thrombolysis	1,182 (63.0)	225 (60.3)	0.328
Hypertension	1,388 (74.2)	261 (70.0)	0.231
Diabetes mellitus	309 (16.6)	65 (17.4)	0.464
Previous stroke	216 (11.6)	48 (12.9)	0.636
Myocardial infarction	158 (8.5)	26 (7.0)	0.376
Hypercholesterolemia	925 (49.5)	170 (45.6)	0.371
Atrial fibrillation	724 (38.7)	126 (33.8)	0.083
Coronary artery disease	398 (21.3)	67 (18.0)	0.315
Peripheral artery disease	109 (5.8)	18 (4.8)	0.069
Smoking	274 (14.7)	71 (19.0)	<0.001
sICH	91 (4.9)	14 (3.8)	0.359
Improvement NIHSS ≥8	669 (38.9)	112 (31.4)	0.008
MRS at 3 months 0–2	623 (33.2)	148 (39.7)	0.016
ODT (min)	71 (46–139)	85 (60–174)	0.003
DNT (min)	35 (15–55)	45 (25–60)	<0.001
OTT (min)	105 (79–138)	124 (100–150)	<0.001

Values are presented as number (%) or median (interquartile range).
CT, computed tomography; MRI, magnetic resonance imaging; WUS, wake up stroke; NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; sICH, symptomatic intracerebral hemorrhage; ODT, onset to door time; DNT, door to needle time; OTT, onset to treatment time.

Table 4. Comparison of baseline characteristics of CT- and MRI-guided WUS/SUO patients treated with mechanical thrombectomy

Characteristic	CT (n=404)	MRI (n=159)	*P*
Age (yr)	73 (62–81)	72 (58–81)	0.339
Female sex	217 (53.7)	79 (49.7)	0.389
Admission NIHSS	16 (11–20)	13 (9–18)	<0.001
Pre-stroke mRS 0–1	350	131	0.632
Thrombolysis	158 (39.1)	82 (51.6)	0.007
Hypertension	304 (75.8)	113 (71.1)	0.025
Diabetes mellitus	87 (21.7)	25 (15.7)	0.230
Previous stroke	55 (13.7)	16 (10.1)	0.287
Myocardial infarction	38 (9.5)	8 (5.0)	0.026
Hypercholesterolemia	204 (50.9)	78 (49.1)	0.036
Atrial fibrillation	155 (38.6)	56 (35.2)	0.054
Coronary artery disease	79 (19.7)	28 (17.6)	0.559
Peripheral artery disease	23 (5.7)	6 (3.8)	0.628
Smoking	55 (13.7)	29 (18.2)	<0.001
sICH	21 (5.2)	5 (3.1)	0.296
Improvement NIHSS ≥8	117 (32.1)	37 (23.6)	0.051
MRS at 3 months 0–2	110 (27.2)	56 (35.2)	0.061
DNT (min)	41 (13–65)	49 (37–67)	0.047

Values are presented as median (interquartile range) or number (%).
CT, computed tomography; MRI, magnetic resonance imaging; WUS, wake up stroke; SUO, unknown onset stroke; NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; sICH, symptomatic intracerebral hemorrhage; DNT, door to needle time.

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Safety and efficacy of CT- or MRI-guided thrombectomy in WUS/SUO

Five hundred sixty-three (25%) were strokes patients with WUS/SUO undergoing MT. These patients showed higher rates of MRI-based imaging (159 [28.2%] vs. 373 [16.6%], *P*<0.001). Admission NIHSS (median 13 vs. 16, *P*<0.001), hypertension (113 [71.1%] vs. 304 [75.8%], *P*=0.025), myocardial infarction (MRI 8 [5%] vs. CT 38 [9.5%], *P*=0.026), and hypercholesterolemia (MRI 78 [49.1%] vs. CT 204 [50.9%], *P*=0.036) showed significant differences favoring MRI-guided patients (Table 4). MRI-guided MT patients showed significantly higher rates of bridging thrombolysis (82 [51.6%] vs. 158 [39.1%], *P*=0.007), however with a significant time delay of 8 minutes in DNT (median 49 minutes vs. median 41 minutes, *P*=0.047). Patients treated with MRI-guided MT showed lower rates of neurological improvement NIHSS ≥8 (62 [39.5%] vs. 185 [50.7%], *P*=0.019); however, the sICH rate did not differ significantly (5 [3.1%] vs. 21 [5.2%], *P*=0.296). Functional outcome mRS 0–2 tended to occur more frequently in the MRI-guided group (56 [35.2%] vs. 110 [27.2%], *P*=0.061); however, these results missed the statistical level of significance. The multivariable analysis showed that MRI-guided MT was equally associated with neurological improvement NIHSS ≥8 (adjusted OR, 0.84; 95% CI, 0.59 to 1.19), functional outcome mRS 0–2 at 3 months (adjusted OR, 0.90; 95% CI, 0.54 to 1.52), occurrence of sICH (adjusted OR, 0.6; 95% CI, 0.2 to 1.77), and mortality at 3 months (adjusted OR, 0.51; 95% CI, 0.18 to 1.45) as compared to CT-guided MT (Table 5).

Table 5. Multivariable logistic regression models comparing MRI (reference) versus CT-guided imaging for IVT/MT in acute stroke

Variable	Adjusted OR	95% CI
IVT only		
sICH	0.82	0.61–1.08
Improvement ≥ NIHSS 4 points	1.09	0.98–1.22
mRS 0–1 at 3 months	0.87	0.71–1.05
IVT and MT		
sICH	0.92	0.51–1.69
Improvement ≥ NIHSS 8	0.97	0.73–1.28
mRS 0–2	0.87	0.65–1.16
WUS/SUO IVT only		
sICH	0.83	0.49–1.4
Improvement ≥ NIHSS 4	0.91	0.72–1.15
mRS 0–1	0.80	0.54–1.19
WUS/SUO IVT and MT		
sICH	0.60	0.2–1.77
Improvement ≥ NIHSS 8	0.74	0.44–1.23
mRS 0–2	0.90	0.54–1.52

MRI, magnetic resonance imaging; CT, computed tomography; IVT, intravenous thrombolysis; MT, mechanical thrombectomy; OR, odds ratio; CI, confidence interval; sICH, symptomatic intracerebral hemorrhage; NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; WUS, wake up stroke; SUO, unknown onset stroke.

Discussion

According to our data, acute stroke treatment using IVT and/or MT seemed to be equally safe and effective independent of the choice of acute imaging. The majority of patients in our cohort received acute imaging using CT (86.7%), which is consistent with previous observations.[8]

Interestingly, CT-guided IVT administration was associated with higher rates of sICH (4% vs. 2.8%) in the univariate comparison. This may eventually be explained by the uneven distribution of risk factors for sICH as age, NIHSS, and vascular risk factors in the CT versus MR groups. Indeed, this difference disappeared after multivariable adjustment.

Previous studies suggested superiority of MRI in safety and efficacy, especially in the extended time window.[9,10] MRI is considered to be more sensitive to ischemic core size, infarct age estimations and bleeding risk surrogates including, e.g., the number of microbleeds therefore probably leading to less sICH and better outcomes after IVT. On the other hand, it seems that MRI may consume approximately 20 minutes more time as compared with CT. We suggest that these features of MRI may counterbalance themselves and that this phenomenon eventually accounts for the observed equipoise between MRI and CT in our study. This is also in line with the observation that the differences seen in the univariate analysis disappear at the step of multivariable adjustment.

The MT rate of 11.6% is comparable to large observational studies.[11] The bridging IVT rate of over 60% did not differ between the CT- and MRI-guided group. This is in line with earlier observations showing no effect of imaging modality on IVT bridging or MT rates.[4] In contrast to previous studies, CT-guided MT was not associated with worse functional neurological outcome,[3] higher rate of bridging IVT,[12] or higher occurrence of sICH.[2,9]

Moreover, in contrast to a recent observational study,[5] our analysis showed a clear delay in the intrahospital MRI workflow to treatment of approximately 20 minutes as compared to CT workflow. These findings were independent of the choice of acute stroke treatment (IVT or MT) and in line with other real word data 3 and also with the results of Extending the Time for Thrombolysis in Emergency Neurological Deficits (EXTEND) study.[13]

The subgroup analysis of WUS/SUO patients revealed a significant higher rate of IVT administration and bridging IVT rates in MRI-guided patients. This is possibly due to the fact that MRI offers in the setting of WUS/SUO more precise information of infarct core size and age leading to higher IVT rates. Moreover, diffusion weighted imaging/fluid attenuated inversion recovery (DWI/FLAIR) mismatch is historically a more common neuroradiological paradigm to indicate acute treatment in WUS in Austria. Previous survey revealed that 69.2% (18 from 26) of participating stroke units used MRI imaging to indicate IVT and MT in the setting of WUS/SUO.[14] CT-guided centers used a combined non-contrast CT/CT perfusion in the extended time window or in case of WUS/SUO.[14] Of importance is that our data indicate no safety or efficacy concerns between initial CT versus MRI imaging also in the setting of WUS/SUO stroke.

The absence of data covering the indication for the particular type of acute stroke imaging has to be mentioned as major limitation. The choice of imaging modality was given by the particular hospital setting, or decided by the stroke teams individually in centers where both modalities were available and might also have changed over the study period. Moreover, information on additional imaging (perfusion, angiography) is not well represented in the registry. As the follow-up at 3 months was not mandatory by legislation until 2020 in this nationwide registry, the number of patients with completed follow-up is lower than in other registries. However, no differences of baseline characteristics, stroke severity, and therapy choice have been found in the comparison of patients with follow-up and those without. As further limitation, a possible bias by indication, the retrospective, non-randomized character and the potential effects of unmeasured confounders should be mentioned. Therefore, the interpretation of our results has to be made with caution, considering all the above-mentioned limitations. The strength of our study, however, is the prospectively collected very large consecutive dataset mirroring a real-world setting, reviewed by a scientific board, and managed by an external independent institution.

Conclusions

The choice of the initial imaging modality seems not to have effect on the safety and functional outcome of IVT and/or MT in acute stroke. Standardized workflows are needed to shorten delays in MRI-guided stroke patients.

Disclosure

The authors have no financial conflicts of interest.

References

1. Zhang XH, Liang HM. Systematic review with network meta-analysis: diagnostic values of ultrasonography, computed tomography, and magnetic resonance imaging in patients with ischemic stroke. *Medicine (Baltimore)* 2019;98:e16360.
2. Köhrmann M, Jüttler E, Fiebach JB, Huttner HB, Siebert S, Schwark C, et al. MRI versus CT-based thrombolysis treatment within and beyond the 3 h time window after stroke onset: a cohort study. *Lancet Neurol* 2006;5:661-667.
3. Macha K, Hoelter P, Siedler G, Knott M, Schwab S, Doerfler A, et al. Multimodal CT or MRI for IV thrombolysis in ischemic stroke with unknown time of onset. *Neurology* 2020; 95:e2954-e2964.
4. Meinel TR, Kaesmacher J, Mosimann PJ, Seiffge D, Jung S, Mordasini P, et al. Association of initial imaging modality and futile recanalization after thrombectomy. *Neurology* 2020;95:e2331-e2342.
5. Provost C, Soudant M, Legrand L, Ben Hassen W, Xie Y, Soize S, et al. Magnetic resonance imaging or computed tomography before treatment in acute ischemic stroke. *Stroke* 2019; 50:659-664.
6. Brainin M, Steiner M; Austrian Stroke Registry for Acute Stroke Units. Acute stroke units in Austria are being set up on a national level following evidence-based recommendations and structural quality criteria. *Cerebrovasc Dis* 2003;15 Suppl 1:29-32.
7. Hacke W, Kaste M, Bluhmki E, Brozman M, Dávalos A, Guidetti D, et al. Thrombolysis with alteplase 3 to 4.5 hours after acute ischemic stroke. *N Engl J Med* 2008;359:1317-1329.
8. Campbell BC, Parsons MW. Imaging selection for acute stroke intervention. *Int J Stroke* 2018;13:554-567.
9. Schellinger PD, Thomalla G, Fiehler J, Köhrmann M, Molina CA, Neumann-Haefelin T, et al. MRI-based and CT-based thrombolytic therapy in acute stroke within and beyond established time windows: an analysis of 1210 patients. *Stroke* 2007;38:2640-2645.
10. Thomalla G, Boutitie F, Ma H, Koga M, Ringleb P, Schwamm LH, et al. Intravenous alteplase for stroke with unknown time of onset guided by advanced imaging: systematic review and meta-analysis of individual patient data. *Lancet* 2020; 396:1574-1584.
11. Rotzinger DC, Mosimann PJ, Meuli RA, Maeder P, Michel P. Site and rate of occlusive disease in cervicocerebral arteries:

 https://doi.org/10.5853/jos.2021.03846

a CT angiography study of 2209 patients with acute ischemic stroke. *AJNR Am J Neuroradiol* 2017;38:868-874.

12. Kim JT, Cho BH, Choi KH, Park MS, Kim BJ, Park JM, et al. Magnetic resonance imaging versus computed tomography angiography based selection for endovascular therapy in patients with acute ischemic stroke. *Stroke* 2019;50:365-372.
13. Ma H, Campbell BC, Parsons MW, Churilov L, Levi CR, Hsu C, et al. Thrombolysis guided by perfusion imaging up to 9 hours after onset of stroke. *N Engl J Med* 2019;380:1795-1803.
14. Krebs S, Posekany A, Ferrari J, Lang W, Sommer P, Gattringer T, et al. Intravenous thrombolysis in wake-up stroke: real-world data from the Austrian Stroke Unit Registry. *Eur J Neurol* 2019;26:754-759.

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