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CLINICAL INVESTIGATIVE STUDY

# Extracranial ultrasound following mechanical thrombectomy in patients with acute stroke

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## Abstract

**Background and Purpose:** Mechanical thrombectomy (MT) is standard care for patients suffering from an ischemic stroke due to a large vessel occlusion. Immediate and follow-up transcranial ultrasound examinations after MT were shown to have a diagnostic benefit. However, it is unclear whether repeated extracranial ultrasound after MT has an additional diagnostic yield, that is, depicts new findings.

**Methods:** Retrospectively, from our prospective database we identified all patients after MT who presented for a follow-up examination between January 2017 and March 2020 and who had received an ultrasound examination after MT and at follow-up. Clinical data were extracted from our database. Ultrasound images of all patients were revisited to identify new findings at follow-up compared to examination after MT.

**Results:** Ninety-one patients were identified appropriate for further analysis, with a mean age of 67.8 ± 16 years. Median National Institute of Health Stroke Scale at admission was 11 ± 8.5 points. At baseline ultrasound, 18 patients (19.8%) had no atherosclerotic alterations and 73 patients (82.2%) had a plaque burden of ≥1 plaque. During follow-up, in 5 patients (5.5%) a pathological finding presented in first examination evolved dynamically, that is, normalized. Vessel status of all other patients was stable, especially, in no patient a new relevant pathological finding occurred.

**Conclusions:** Although sonographic normalization of pathologic findings was observed, pathologic new findings were not detected during follow-up. This study provides first data for a discussion of the role of ultrasound in a structured stroke care after MT. However, larger studies are required to improve the understanding.

KEYWORDS
extracranial ultrasound, follow-up, mechanical thrombectomy, stroke

## INTRODUCTION

Mechanical thrombectomy (MT) has been proven effective for treatment of patients suffering from an ischemic stroke due to large vessel occlusion.[1] Accordingly, MT is now standard care and numbers of applied mechanical thrombectomies are rising constantly.[2] Despite an optimized treatment for acute ischemic stroke, optimal and standardized follow-up of stroke patients, in particular following thrombectomy, has yet to be determined.[3]

There is current evidence that immediate and follow-up transcranial color-coded ultrasound (TCCD) after MT provides useful information and affects patients monitoring.[4,5,6] Although extracranial ultrasound is established as an important part of acute stroke diagnostic and workup of stroke etiology,[7] the relevance of routine extracranial

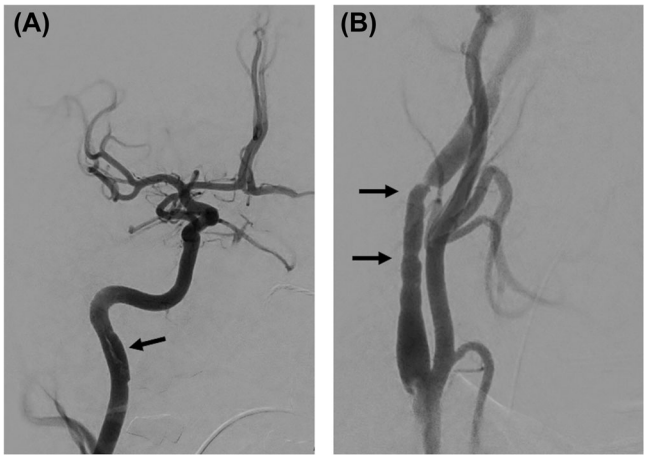


**FIGURE 1** Angiographic periinterventional complications. (A) Periinterventional dissection of the right carotid artery following thrombectomy. (B) Extracranial vasospasm of the internal carotid artery following thrombectomy. Black arrow indicates pathology

ultrasound following MT is poorly studied during short-term (ie, days) follow-up and has not been studied for mid-term (ie, months) follow-up yet.[8] Though MT may cause vessel injury at intra- or extracranial sites, for example, carotid artery dissections or vasospasms[9,10] (Figure 1), it is unclear whether ultrasound follow-up detects these findings and has an additional diagnostic benefit. Given the growing number of patients receiving MT for acute stroke treatment,[2] a better understanding of this topic could help to determine an optimal outpatient sonographic follow-up regime and to avoid unnecessary examinations including the risk of incidental findings.[11]

We therefore wondered whether new pathological findings appear during regular mid-term sonographic extracranial follow-up after MT or if pathological findings presenting at first examination evolve further or disappear.

## METHODS

### Study population

Following MT, all patients were invited for follow-up visits 3 months after MT including an extracranial ultrasound as part of clinical practice in our hospital. From our database, all patients were identified who had received MT for acute stroke treatment and who had appeared for a follow-up examination between January 2017 and March 2020. All patients who received extracranial ultrasound directly after MT, that is, during initial hospital stay, and during follow-up were included for analysis. Patients who received emergent extra-/intracranial stenting or suffered from posterior circulation stroke were excluded.

Clinical and neuroradiological data (such as age, sex, premedication, catheter devices, NIHSS [National Institutes of Health Stroke Scale] scores) were retrieved from medical records and our database.

Given the anonymous and retrospective study design, this monocentric analysis was approved by our local ethics committee (122/18S).

### Treatment protocol

All patients were treated according to our hospital's daily routine standard operating procedures in line with standard care in Germany for stroke treatment and work-up of stroke etiology as described before.[12] For MT, up to date aspiration catheters, stent-retriever devices, or a combination of both was used. After MT, patients were treated at our stroke or intensive care unit. As part of the diagnostic workup of stroke etiology, each patient received ultrasound of brain supplying vessels following MT and during follow-up.

### Neurosonography

#### Data acquisition

Color-coded extracranial ultrasound was performed by long-term experienced sonographers as part of routine diagnostic. For image acquisition, the following devices were used: Siemens Acuson S2000 (9L4 linear probe) and Siemens Acuson Juniper (11L4 linear probe) (Erlangen, Germany). All images were digitally stored.

A standard neurosonographic examination includes an examination of the extracranial arteries, including cervical segment of the carotid artery and foraminal segments of the vertebral artery. As patients with posterior circulation stroke were excluded, only carotid arteries were analyzed for this study. The first ultrasound performed after hospitalization and after MT was defined as baseline ultrasound. The next available neurosonography after discharge was defined as follow-up ultrasound.

#### Data analysis/outcome parameter

In addition to analysis of written ultrasound reports, all sonographic studies were revisited to determine initial plaque burden at baseline and to identify suspicious findings at baseline and changes during follow-up.

Plaque burden was classified according to the number of plaques detected with ultrasound.[13] As a new finding we defined an obviously visible dynamic between both examinations, such as a recanalization or re-occlusion of any vessels or dis-/appearance of mobile structures.

### Statistics

Statistical analysis was performed using IBM SPSS statistics, version 26. Mean values with standard deviation were calculated for continuous variables and median values with interquartile range (IQR) for categorized variables. The parameters of the two groups were compared using the Mann-Whitney *U*-test or Fisher's exact test depending on the type of variables analyzed; $p < .05$ was considered significant.

**TABLE 1** Comparison of study population to excluded patients

| | Study population ($n = 91$) | Excluded patients ($n = 68$) | $p$-value |
|---|---|---|---|
| Age, years median (IQR) | 73 (56-80) | 65.5 (58-74) | .322 |
| Sex, female (%) | 46 (51) | 45 (66) | .054 |
| NIHSS at admission, median (IQR) | 11 (6-15) | 8.5 (5-15) | .279 |

Abbreviations: IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale; *n*, number of subjects.

**TABLE 2** Clinical baseline data

| | Study population ($n = 91$) |
|---|---|
| General data | *n (%)* |
| Age, years, median (IQR) | 73 (56-80) |
| Sex, female | 46 (51) |
| Premedication | |
| Anticoagulation | 26 (28.6) |
| Platelet inhibition | 25 (27.5) |
| Lipid lowering | 25 (27.5) |
| Preexisting disease | |
| Atrial fibrillation | 42 (46.2) |
| Arterial hypertension | 54 (59.3) |
| Dyslipidemia | 27 (29.7) |
| Nicotine | 13 (14.3) |
| Prior stroke | 18 (19.8) |
| Diabetes mellitus | 18 (19.8) |
| Current stroke | |
| Anterior circulation | 91 (100%) |
| -Tandem occlusion | 4 (4%) |
| NIHSS at admission, median (IQR) | 11 (6-15) |
| Thrombolysis | 42 (46) |
| Mechanical thrombectomy | 91 (100) |
| -Reported angiographic complication[a] | 5 (5.5%) |
| -TICI Score ≥2b | 86 (95%) |
| -Additional stenting | 0 (0%) |
| Stroke etiology (TOAST) | |
| −1 | 7 (7.7%) |
| −2 | 51 (56%) |
| −4−5 | 8 (8.8%) |
| | 25 (27.5%) |

Abbreviations: IQR, interquartile range; TICI, thrombolysis in cerebral infarction; TOAST, Trial of Or Trial of Org 10172 in Acute Stroke Treatment; *n*, number of subjects.

[a]Following extracranial periprocedural angiographic complications were reported: vasospasm $n = 2$, cervical artery dissection $n = 2$, carotid artery perforation with extravasation $n = 1$.

## RESULTS

### Study population

In total, 159 patients were identified who received an ultrasound examination following MT for acute stroke treatment and during follow-up. Patients who received emergent extra- or intracranial stenting ($n = 50$) or suffered from a stroke in the posterior circulation ($n = 18$) were excluded from analysis, resulting in a study population of 91 patients. Both groups did not differ concerning age, sex, or NIHSS at admission (see Table 1). For clinical data of the study population, see Table 2.

### Sonographic baseline parameters

Sonographic examination of the cerebralAQ5 vessels was performed at day 1 (IQR 1-2) after the initial stroke event. As remarkable pathologic finding of the carotid arteries, in one case (1.1%) an extracranial vasospasm of the carotid artery following MT was visible. In another case (1.1%), a thrombus at the carotid bifurcation was detected. For further sonographic baseline characteristics on the number of plaques, stenosis, and carotid occlusions, see Table 3.

### Sonographic follow-up

Follow-up ultrasound was performed in average 3.5 months after the index stroke with MT. Median modified Rankin Scale at follow-up was $1 \pm 2$.

In five cases (5.5%), the vessel status was relevantly altered compared to ultrasound directly after MT, with a normalization in each case (Table 3 and Figure 2). The other 86 patients (94.5%) had a stable extracranial vessel status. Here, no new pathologic finding such as a mobile structure or progressive stenosis was detected.

## DISCUSSION

We present a retrospective extracranial sonographic follow-up study on patients receiving MT for acute stroke treatment. The major finding of our study is an occurrence of sonographic extracranial dynamic changes, that is, normalization in 5.5% of our study population. New pathological findings were not found in our collective after follow-up extracranial sonography.

In all 5 patients with a significantly altered ultrasound result, these findings reflected a normalization of the vessel status. Regression of a local thrombus and carotid artery dissection is a well-characterized phenomenon.[14,15] Though this is a common finding, it requires sonographic follow-up to guide appropriate treatment. In two cases, the local normalization was not spontaneous as both patients received carotid endarterectomy for treatment of underlying carotid artery stenosis. Remarkable is the case of a carotid vasospasm following MT,

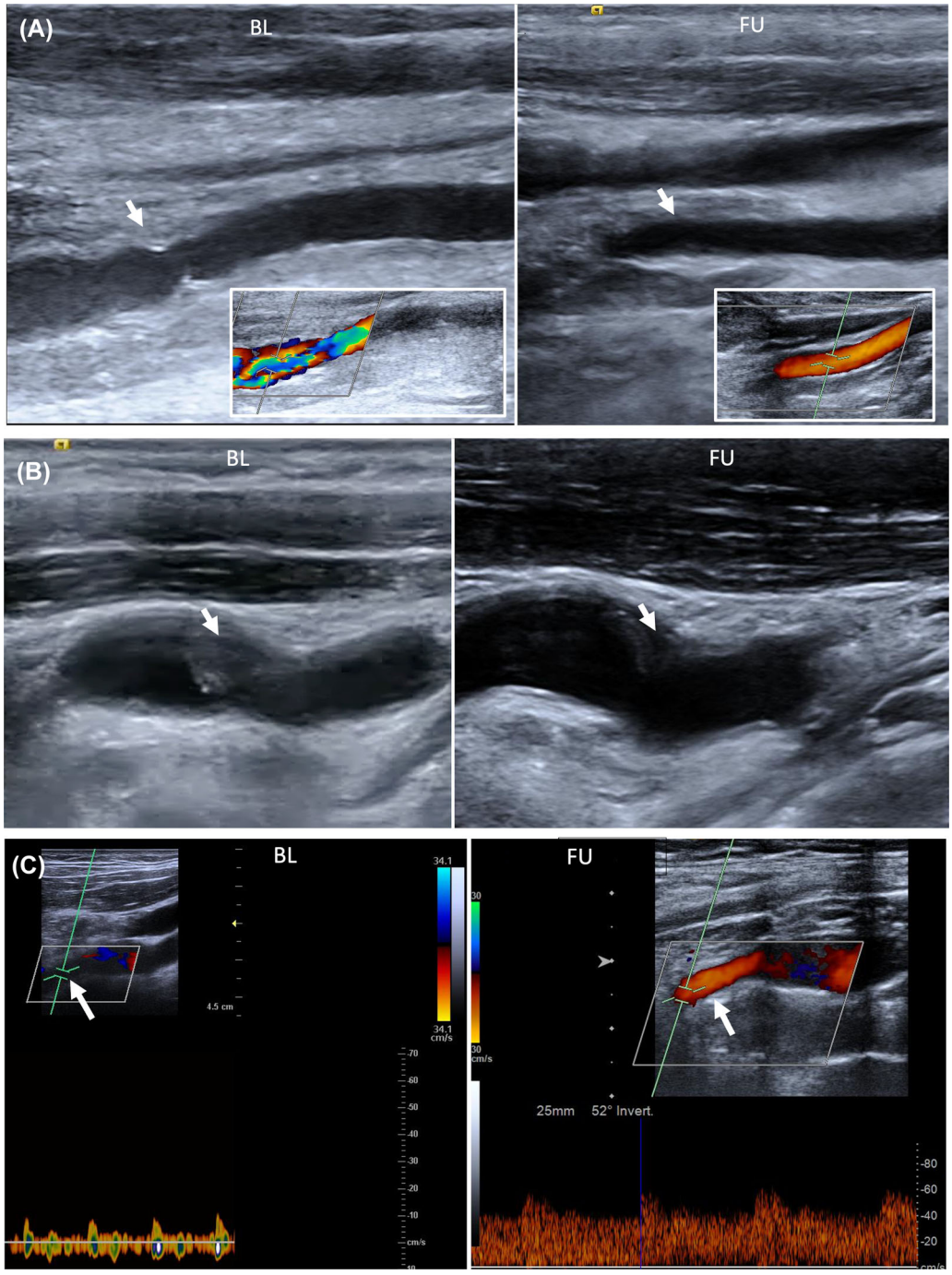


**FIGURE 2** Altered sonographic extracranial findings during follow-up. (A) Vasospasm of the external carotid artery after mechanical thrombectomy that disappeared during follow-up. Besides morphologic pathology in the B-Mode, normalization of the blood flow is clearly recognizable with the color mode (white box). (B) Thrombus at the carotid bifurcation at baseline with regression and organization during follow-up. (C) Recanalization of a distal carotid artery occlusion during follow-up due to distal cervical artery dissection with restored blood flow. Pertinent findings are indicated with white arrows. BL, baseline examination; FU, follow-up examination

which is the first vasospasm following MT diagnosed by ultrasound published to date to our knowledge. Though occurrence of vasospasms, in particular as proximal as in our patient, is low,[9,10] knowledge of this sonographic transient finding is important for clinicians to avoid misdiagnosis of local vasculopathy responsible for ipsilateral stroke. To further address the frequency of such local findings, extracranial ultrasound examination directly following MT should be analyzed in the future, irrespective of follow-up data.[8] In summary, given the frequency of 5.5% of a dynamic change in patients with a pathologic finding at baseline, follow-up ultrasound seems reasonable based on our data, in particular, as ultrasound is a widely available and noninvasive diagnostic tool.

**TABLE 3** Carotid ultrasound data: Baseline and outcome

| | Study population ($n = 91$) |
|---|---|
| Baseline | *n* (%) |
| Plaque burden | |
| -0 plaques | 18 (19.8) |
| -1-2 plaques | 36 (39.6) |
| -3-4 plaques | 32 (35.2) |
| ≥5 plaques | 5 (5.5) |
| Carotid stenosis ≥ 50% | 4 (4.4) |
| Carotid occlusion | 3 (3.3) |
| Outcome | |
| Stable finding | 86 (94.5) |
| Altered vessel status | 5 (5.5) |
| -Kind of finding | -Regredient carotid vasospasm (Figure 2A) |
| | -Regredient carotid thrombus (Figure 2B) |
| | -Regredient carotid dissection (Figure 2C) |
| | -CEA for internal carotid stenosis twice |

Abbreviations: CEA, carotid endarterectomy; *n*, number of subjects.

In none of our patients we identified any new pathologic finding during follow-up, neither as sequela of MT nor as an incidental finding. Though intracranial hemodynamics seem to be highly dynamic following MT in the acute setting,[4,6] during mid-term follow-up transcranial new findings are less frequent, which is known from TCCD and angiographic follow-up data.[5,16] According to our results, this lower dynamic during mid-term transcranial follow-up seems to be similar for extracranial vessel following MT. Despite our selected study population, this may indicate that extra- and intracranial ultrasound (which mostly belongs together from a neurosonographic perspective) may be of diagnostic value in particular in the acute setting. Concerning a mid-term follow-up, so far, at least all patients with a pathologic finding at baseline should receive an ultrasound follow-up. Given the high number of patients receiving MT, a standardized recommendation for follow-up would be helpful, as this is lacking so far.[3] We believe this study provides a first dataset for further discussions and studies how to implement ultrasound in post-stroke care after MT. It is important to note that all patients who obviously require standardized sonographic follow-up irrespective of MT following cervical artery stenting were excluded from our analysis.

Aside from the retrospective design, our study has further limitations. Most importantly, a selection bias is present, because only patients who presented to our outpatient clinic received a follow-up ultrasound and were subsequently included for analysis. Further, extracranial ultrasound following the index event was not performed at a standardized time point. For example, the rate of vasospasms might be underestimated.

Despite the discussed limitations, we believe our findings are of importance, because sonographic follow-up data after MT are sparse but are required to establish structured follow-up care after stroke. Further, we present the first sonographic case of an extracranial vasospasm following MT. Although MRI and angiographic studies are particularly helpful for hospitals, ultrasound follow-up data after MT may support decision-making in outpatient follow-up of stroke patients. Therefore, larger and prospective studies are required to provide further data.

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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

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