

CASE REPORT

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Angiographically occult in-stent protrusion detected by intravascular ultrasound during carotid artery stenting: a case report

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Abstract

Background Carotid artery stenting (CAS) is an established revascularization strategy for carotid stenosis, but periprocedural ischemic events remain a concern. In-stent protrusion, representing plaque protrusion and/or adherent thrombus, may be clinically relevant and can be underestimated by angiography alone. Intravascular ultrasound (IVUS) provides cross-sectional visualization of the stent lumen and may detect lesions not apparent on digital subtraction angiography.

Case presentation We report the case of a 92-year-old man of Japanese ethnicity with symptomatic right internal carotid artery tandem stenoses treated with CAS under balloon protection. Completion angiography showed no intraluminal defect; however, IVUS demonstrated marked protrusion within the distal stent. Immediate rescue with an additional overlapping stent under re-occlusion eliminated the protrusion on repeat IVUS. The patient recovered without complications and was discharged home on postoperative day 4.

Conclusions This case highlights that IVUS may detect angiographically occult in-stent protrusion and may help guide prompt intraprocedural rescue and confirmation of lumen optimization.

Keywords Carotid artery stenting, Intravascular ultrasound, In-stent protrusion, Plaque protrusion, Tandem stenosis, Carotid dissection, Case report

Background

Carotid artery stenting (CAS) is widely performed for carotid stenosis; however, embolic complications remain a major limitation. One proposed mechanism for periprocedural ischemic events is in-stent protrusion, which includes plaque protrusion and/or thrombus formation within the stent lumen [1–3]. Although

completion angiography is routinely used for luminal assessment, subtle intraluminal abnormalities may be angiographically occult [4, 5].

Intravascular ultrasound (IVUS) provides high-resolution, cross-sectional imaging of the vessel wall and stent lumen, enabling evaluation of plaque morphology and composition [6, 7] as well as the stent–artery interface. In a large cohort, plaque protrusion confirmed by both angiography and IVUS was associated with a significantly higher incidence of periprocedural ischemic stroke, and additional intrastent projections were detected by IVUS despite negative angiographic findings [8]. Prior reports suggest that IVUS can identify angiographically occult in-stent protrusion and guide immediate corrective maneuvers, including additional balloon angioplasty or

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stent-in-stent implantation [5, 9, 10]. Here, we present a case in which IVUS revealed marked angiographically occult in-stent protrusion after CAS and directly altered intraprocedural management.

Case presentation

A 92-year-old man of Japanese ethnicity presented with acute left-sided weakness and left hemispatial neglect ($T=0$, defined as the day of symptom onset, initial presentation, and admission). He had no headache, facial pain, or neck pain and denied any recent trauma. On examination, he was alert and oriented, with no anisocoria. Blood pressure was 182/85 mmHg and heart rate was 60 beats/minute with a regular rhythm. Although formal manual muscle testing did not show marked weakness, Barre and Mingazzini signs were positive on the left, and the National Institutes of Health Stroke Scale score was 4. His medical history included hypertension and diabetes mellitus treated with oral medications. His family history was unremarkable. Before admission, he was independent in activities of daily living and had a habit of light exercise. He had a smoking history from age 20 to 62 years and consumed approximately 20 g of alcohol on most days.

Diffusion-weighted magnetic resonance imaging performed ($T=0$) demonstrated multiple scattered infarcts in the right cerebral watershed region (Fig. 1). Cervical magnetic resonance angiography suggested tandem stenoses of the right cervical internal carotid artery (ICA). Medical therapy was initiated on the day of admission ($T=0$) with prasugrel 3.75 mg/day, aspirin 100 mg/day, and pitavastatin 2 mg/day. Subsequent three-dimensional computed tomography angiography (CTA) performed at $T=3$ days and carotid ultrasonography performed at $T=9$ days demonstrated (1) severe stenosis (approximately 95%) in the distal cervical ICA just proximal to the carotid canal, with a morphology suggestive of a dissecting lesion (possible flap and pseudo-lumen-like appearance), and (2) moderate stenosis (approximately 60%) at the ICA origin with unstable plaque features (Fig. 1). Based on these findings, CAS was performed at $T=14$ days. Carotid endarterectomy was considered less suitable because the distal lesion was located high in the cervical ICA, just proximal to the carotid canal, where surgical exposure would be more challenging. In addition, an endovascular approach allowed both the distal and proximal lesions to be treated in a single session.

An occlusion guidewire (Optimal wire; Tokai Medical Products, Kasugai, Aichi, Japan) and an IVUS catheter (Eagle Eye Platinum; Volcano Corporation, San Diego, CA, USA) were used to evaluate the lesions. An 8 Fr balloon guiding catheter (OPTIMO; Tokai Medical Products, Kasugai, Aichi, Japan) was used together with

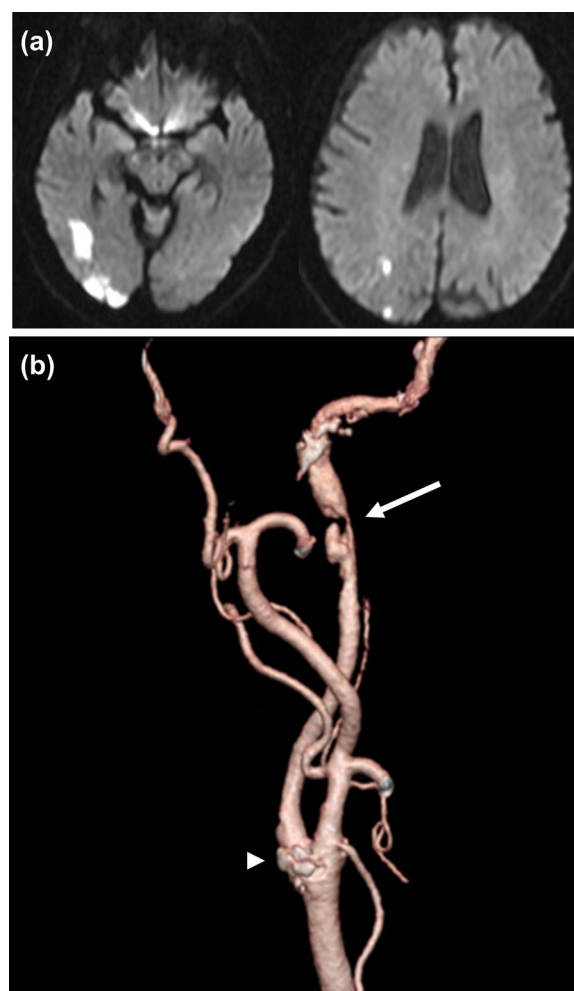


Fig. 1 Preoperative imaging findings. **a** Diffusion-weighted magnetic resonance imaging shows multiple scattered acute infarcts in the right cerebral watershed territory. **b** Three-dimensional computed tomography angiography demonstrates tandem stenoses of the right internal carotid artery (ICA): 60% stenosis at the ICA origin (white arrowhead) and 95% stenosis in the distal cervical segment just proximal to the carotid canal (white arrow), measured by North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria

the occlusion guidewire to achieve combined proximal balloon occlusion and distal balloon protection (double-balloon protection). This strategy was selected to minimize distal embolization during treatment of the tandem lesions and because previous reports have suggested that double-balloon protection may reduce the incidence of new postoperative diffusion-weighted imaging lesions during CAS [11]. The wire was advanced to the horizontal segment of the petrous ICA, where distal balloon protection was performed (with proximal balloon occlusion) to arrest ICA flow. After predilatation with a 3.0×40 mm balloon catheter (Shiden; Kaneka Medical

Products, Tokyo, Japan) at 8 atm for 5 seconds, a closed cell stent (Carotid Wallstent Monorail 6×21 mm; Boston Scientific, Marlborough, MA, USA) was deployed across the distal cervical ICA lesion. A second stent (Carotid Wallstent Monorail 8×29 mm) was then deployed at the ICA origin without predilatation. Postdilatation of both stented segments was performed using a 4.0×40 mm balloon catheter (RX Genity; Kaneka Medical Products) at 8 atm for 5 seconds. Blood aspiration (60 mL) through an aspiration catheter did not yield macroscopic debris.

After restoring flow, completion common carotid angiography showed no in-stent filling defect or obvious plaque/thrombus protrusion. In contrast, IVUS demonstrated marked intraluminal protrusion within the distal stent, consistent with plaque protrusion and/or adherent thrombus (Fig. 2). Flow arrest with balloon protection was re-established, and an additional overlapping stent (Carotid Wallstent Monorail 6×21 mm) was deployed within the distal stent (“stent-in-stent”), followed by repeat postdilatation using the same balloon settings. Additional aspiration (80 mL) again yielded no apparent debris. After final flow restoration, repeat IVUS confirmed resolution of the in-stent protrusion and an acceptable stent lumen. The procedure was completed without angiographic complications.

The postoperative course was uneventful. No new neurological deficits occurred, and the patient was discharged home on postoperative day 4 ($T=18$ days). At outpatient follow-up 57 days after the procedure ($T=2$ months), he remained neurologically stable, and follow-up CTA demonstrated good patency of the treated lesions without evident restenosis or recurrent in-stent protrusion (Fig. 3). At 1 year after the procedure, follow-up carotid ultrasonography showed good stent patency, with no evidence of in-stent plaque protrusion (Fig. 4). A timeline summarizing the clinical course, imaging findings, treatment milestones and neurological outcomes is provided as Fig. 5.

Discussion and conclusions

This case demonstrates a clinically important limitation of angiography-only assessment immediately after CAS. Despite an apparently normal completion angiogram, IVUS revealed marked in-stent protrusion within the distal stent, prompting immediate corrective treatment. Prior work supports that IVUS is more sensitive than angiography for identifying protrusion. Shinozaki et al. detected plaque protrusion in 7.8% of CAS procedures by IVUS, whereas angiography identified protrusion in only 2.6% in the same cohort, and protrusions were corrected with additional ballooning and/or stent-in-stent implantation with disappearance on final IVUS [9]. In a larger IVUS-guided cohort, Kotsugi et al. reported that plaque

protrusion confirmed on both digital subtraction angiography and IVUS was associated with a substantially higher risk of periprocedural ischemic stroke, and they also identified additional IVUS-visible intrastent projections in patients without angiographic protrusion [8]. Collectively, these observations suggest that angiography can underestimate clinically relevant intraluminal abnormalities after CAS.

The discrepancy between angiography and IVUS is plausible because angiography provides a two-dimensional lumenogram, whereas IVUS provides circumferential cross-sectional imaging of the stent lumen and vessel wall [12]. Other intravascular imaging modalities available for the assessment of carotid lesions include optical coherence tomography (OCT) and angioscopy [13, 14]. OCT offers higher spatial resolution and can depict plaque protrusion and stent malapposition in greater detail; however, its penetration depth is shallower, and image acquisition generally requires transient flow arrest and blood clearance [13]. Angioscopy enables direct visualization of the luminal surface and may facilitate detailed assessment of surface plaque protrusion and plaque characteristics, but its evaluation is limited to the lesion surface and also requires blood clearance [13, 14]. In this case, IVUS was considered more suitable for real-time intraprocedural assessment during CAS because it could be used in the presence of blood flow and allowed broader evaluation of the entire lesion, including vessel diameter, lesion length, plaque characteristics, stent expansion, apposition, and lesion coverage [12–14]. Although IVUS was feasible and informative in this case, potential technical challenges should be acknowledged, including the need for careful catheter manipulation within the stented segment and the theoretical risk of dislodging intraluminal material during device passage, particularly in the presence of fragile plaque or thrombus.

When in-stent protrusion is identified by IVUS, its management is not standardized and likely depends on timing, morphology, and suspected composition [2]. In the present case, because a large protrusion was identified intraprocedurally under protection, balloon occlusion was re-established and an overlapping stent was deployed. Repeat IVUS, rather than angiographic appearance alone, was then used to confirm resolution before the procedure was concluded [5, 10].

A secondary consideration in this patient was the distal lesion morphology, which was located just proximal to the carotid canal at a high cervical (C1–C2) level and appeared highly eccentric and flap-like, raising a dissection-like differential. Imaging-based studies suggest that extracranial ICA dissections often originate near the skull base: Downer et al. reported that the origin of spontaneous extracranial ICA dissection is typically adjacent

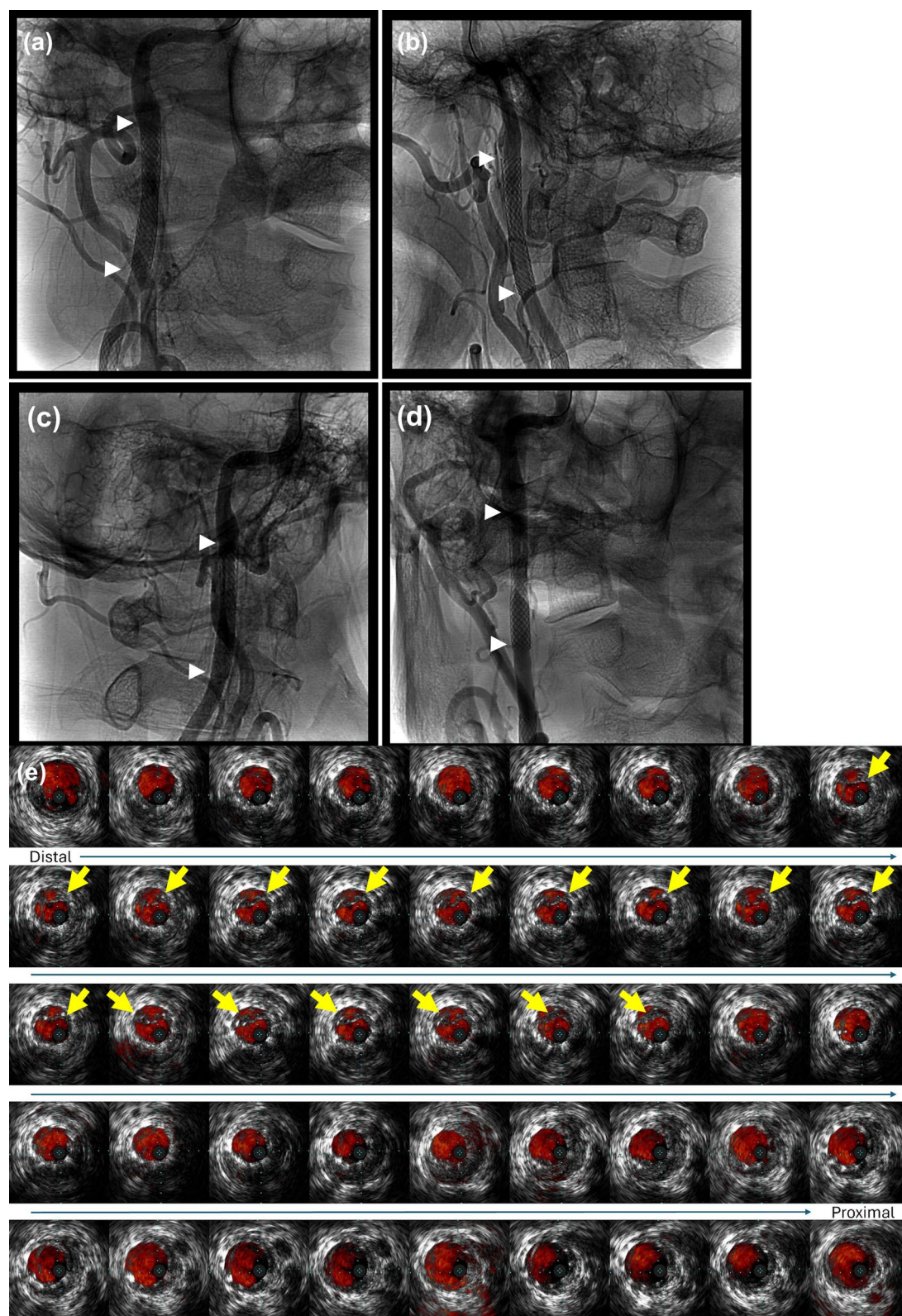


Fig. 2 Intraoperative assessment after initial stent deployment. **a–d** Completion angiography in the anteroposterior (**a**), lateral (**b**), right oblique (**c**), and left oblique (**d**) projections shows no obvious in-stent filling defect or protrusion. White arrowheads indicate the proximal and distal ends of the distal stent. **e** Corresponding intravascular ultrasound imaging within the distal stent demonstrates prominent angiographically occult in-stent protrusion consistent with plaque and/or thrombus (yellow arrows)

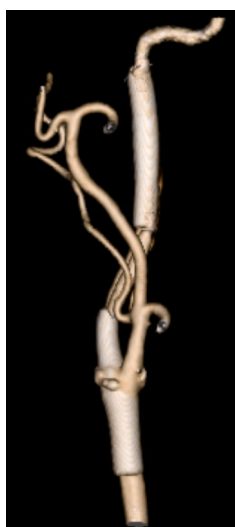


Fig. 3 Follow-up computed tomography angiography obtained 57 days after the procedure demonstrates good patency of the treated right internal carotid artery lesions, without evident restenosis or recurrent in-stent protrusion

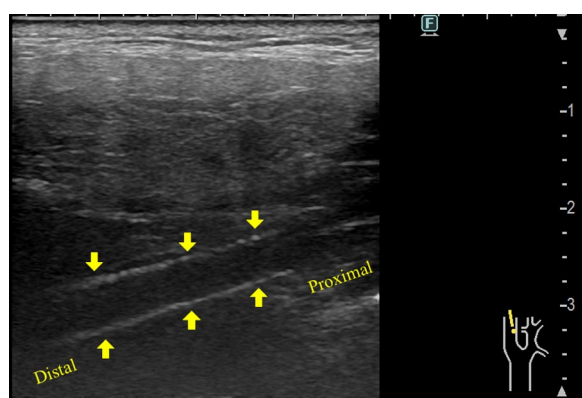


Fig. 4 Follow-up carotid ultrasonography obtained 1 year after the procedure demonstrates good stent patency, without evidence of in-stent plaque protrusion

to the skull base, and that dissections frequently involve the distal cervical ICA [15]. In a trauma center cohort, Lleva et al. described segment-dependent patterns, with traumatic dissections more often occurring at a higher cervical mobile segment (segment III, beginning around the level of the second cervical vertebra), whereas spontaneous dissections were more commonly located near arterial origins [16]. Although our patient denied antecedent trauma and the lesion was treated as a stenotic target for CAS, its high cervical location and dissection-like morphology underscore the possibility of eccentric intraluminal pathology that may be difficult to appreciate on angiography.

Clinical features may raise suspicion for cervical artery dissection but cannot reliably exclude it. Pain is common in cervical artery dissection, but it is not universal [17]. Headache, facial pain, or neck pain is a well-described manifestation and, in some patients, may be the only clinical clue prompting vascular evaluation [18]. In the present case, however, the patient remained entirely free of headache, facial pain, or neck pain throughout the clinical course despite a lesion with dissection-like features. This absence of pain reinforces that symptom-based screening alone is insufficient and should not preclude careful intraprocedural luminal assessment when intervention is performed.

Overall, the present case adds to the existing evidence by illustrating that IVUS can detect clinically relevant angiographically occult in-stent protrusion, consisting of plaque and/or thrombus, and that IVUS findings may influence intraprocedural decision-making in selected clinical situations. In this case, incorporating IVUS as a completion assessment enabled prompt stent-in-stent rescue under re-occlusion and confirmation of protrusion elimination, which may help reduce embolic risk when angiography alone appears reassuring.

Abbreviations

CAS	Carotid artery stenting
IVUS	Intravascular ultrasound
ICA	Internal carotid artery
CTA	Computed tomography angiography
OCT	Optical coherence tomography

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Author contributions

Yuko Tsurumi drafted the manuscript. Arihito Tsurumi and Hayato Yokoyama performed the procedure and contributed to clinical management. Norie Kikuchi, Ryusei Zako, and Osamu Hososhima collected clinical data. Takaaki Ishikawa provided critical revisions. All authors read and approved the final manuscript.

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Data availability

All relevant data supporting the findings of this case report are included within the article. Additional data are not publicly available due to patient confidentiality but may be made available from the corresponding author on reasonable request, subject to institutional regulations and ethical considerations.

Declarations

Ethics approval and consent to participate

Ethical approval was not required for this single case report, in accordance with the institutional policy.

Consent for publication

Written informed consent was obtained from the patient for publication of this case report and any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

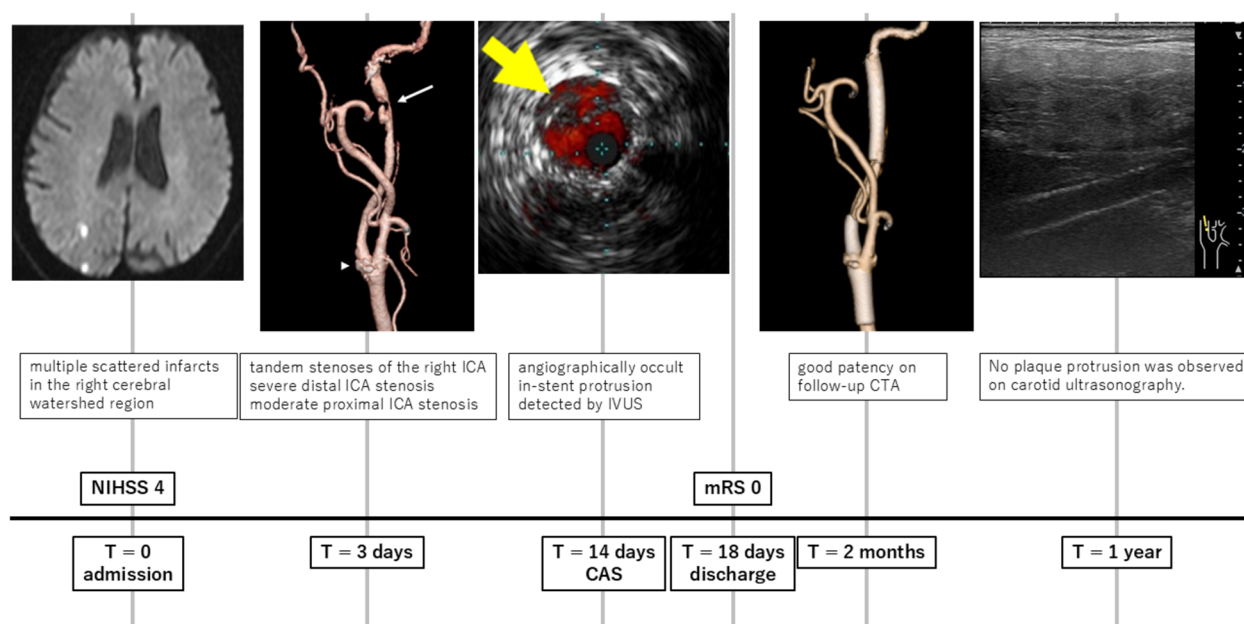


Fig. 5 A timeline summarizing the clinical course, imaging findings, treatment milestones, and neurological outcomes. T=0: Symptom onset and admission. NIHSS National Institutes of Health Stroke Scale score, ICA internal carotid artery, IVUS intravascular ultrasound, CAS carotid artery stenting, CTA computed tomography angiography, mRS modified Rankin Scale score

Competing interests

The authors declare that they have no competing interests.

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