

Evaluation of flow dynamics in dSINE (distal Stent graft-Induced New Entry) using 4D flow MRI

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AUTHOR CONTRIBUTIONS

All authors were involved in reviewing the final draft of the manuscript. All authors have made a significant contribution to preparing the case report.

CONFLICT OF INTEREST: The authors declare no conflicts of interest.

CONSENT: The patient has given written informed consent for the publication of this case report

DATA AVAILABILITY STATEMENT

All data regarding this case has been reported in the manuscript. Please contact the corresponding author if you are interested in any further information.

Abstract:

In cases of distal stent graft-induced new entry (dSINE), analysis using 4D flow MRI revealed accelerated flow into the false lumen and observed wall shear stress (WSS) elevation, prompting a decision for false

lumen expansion. Thoracic endovascular aortic repair (TEVAR) was performed, resulting in rethrombosis of the false lumen.

Key Clinical Message

In cases of distal stent graft-induced new entry (dSINE), analysis using 4D flow MRI revealed accelerated flow into the false lumen and observed wall shear stress (WSS) elevation, prompting a decision for false lumen expansion. Thoracic endovascular aortic repair (TEVAR) was performed, resulting in rethrombosis of the false lumen.

Introduction:

Total Arch Replacement (TAR) using a Frozen Elephant Trunk (FET) is performed for chronic type B aortic dissection, with reported successful thrombosis of the false lumen. However, when distal stent graft-induced new entry (dSINE) occurs in the postoperative period, the blood flow within the false lumen remains unclear. In this study, 4D flow MRI was employed for blood flow evaluation in dSINE cases, providing actual measurements of flow velocity and direction, unlike contrast-enhanced CT simulations. Accelerated flow from the true lumen to the false lumen was confirmed, along with an increase in WSS within the false lumen, predicting future enlargement. Consequently, TEVAR was performed for dSINE, resulting in favorable rethrombosis of the false lumen.

Case:

A male in his 60s experienced acute type A aortic dissection in 2015 and underwent Bentall's operation. In 2020, contrast-enhanced CT revealed an open false lumen from the distal arch to the abdominal aorta with an enlarged false lumen, leading to total arch replacement with FET. Postoperatively, thrombosis of the false lumen progressed, and the diameter of the distal arch decreased (Fig 1(A)). In 2023, the patient presented with chest and back pain. Contrast-enhanced CT showed blood flow in the previously thrombosed false lumen and an enlargement of the false lumen diameter (Fig. 1(B)(C)). 4D Flow MRI revealed accelerated flow from the true lumen to the false lumen at the distal end of the FET (Fig. 2(A)(B)), along with an increase in wall shear stress at the site where the flow from the true lumen to the false lumen reached (Fig. 2(C)). These findings led to the decision that the false lumen diameter would further enlarge.

The strategy was to perform TEVAR for new entry closure. Aortic angiography showed high-velocity blood flow from the true lumen to the false lumen at the distal end of the stent graft (Fig. 3(A)(B)). TEVAR was performed for dSINE, resulting in the disappearance of blood flow into the false lumen, and the surgery was concluded (Fig. 3C). Postoperative CT showed thrombosis of the false lumen and a reduction in its diameter (Fig. 3D). After 6 months, the false lumen was thrombosed, and its diameter continued to shrink.

Discussion:

Chronic aortic dissection poses a risk of aortic diameter enlargement and rupture in the chronic phase. Therefore, imaging diagnosis with CT to monitor the aneurysmal diameter is strongly recommended. Reports on the prognosis of chronic aortic dissection have suggested that cases with an open false lumen have a poorer life prognosis than cases with a closed false lumen, indicating a potential link between blood flow within the false lumen and the enlargement or rupture of the aortic aneurysm in the chronic phase.¹⁾ Treatment with FET for total arch replacement has been reported to achieve good thrombosis of the false lumen in chronic aortic dissection. When performing total arch replacement, FET, compared to the conventional Elephant Trunk (ET) method for distal anastomosis, facilitates a more central anastomosis in the proximal portion of the arch, making peripheral anastomosis easier and reducing blood loss. Additionally, the insertion of a reinforced FET with a stent graft allows for the expectation of thrombotic occlusion and subsequent disappearance of the false lumen in the descending thoracic aorta during the chronic phase. However, complications such as dSINE may occur in the chronic phase as a result of FET. dSINE is the new entry of the stent graft's distal end, leading to the generation of new blood flow from the true lumen to the false lumen, causing enlargement of the false lumen. After the FET procedure, dSINE occurred in 6.5% of patients in the chronic setting²⁾. Excessive oversizing of the stent graft relative to the true lumen and the

spring-back force of the stent graft contribute to SINE formation. Generally, dSINE is asymptomatic and incidentally discovered during regular follow-up CT scans. However, approximately 5% of cases present with symptomatic chest or back pain.³⁾ Typical CT images show the distal part of the stent graft inserted into the true lumen detaching from the intima of the aorta, protruding into the false lumen, and resuming blood flow into the false lumen or enlargement of the false lumen.

4D Flow MRI is a non-invasive imaging technique that expands 2D phase-contrast MRI in three dimensions. It allows for the direct measurement of blood flow, including flow from the true lumen to the false lumen, and wall shear stress (WSS) within the aorta in cases of aortic dissection. In this study, 4D Flow MRI was used for the first time to analyze blood flow in a case of dSINE. The analysis of aortic dissection with 4D MRI indicates that if accelerated blood flow and localized increases in WSS are observed in the remaining dissected area from the true lumen to the false lumen, factors contributing to remote enlargement are likely.⁴⁾

In the case of dSINE, as in cases of chronic open false lumen aortic dissection, accelerated blood flow from the true lumen to the false lumen was observed, suggesting further enlargement. Thus, TEVAR was chosen⁵⁶⁾, and good thrombosis of the false lumen was achieved. However, regular follow-up with CT imaging is necessary due to the risk of arterial expansion and re-dissection.

Conclusion:

In contrast to blood flow simulations using CT, we conducted blood flow analysis of dSINE cases using measurable 4D Flow MRI. In this case, 4D Flow MRI revealed accelerated blood flow into the newly formed false lumen and an increase in WSS, indicating factors contributing to the enlargement of the false lumen.

AUTHOR CONTRIBUTIONS

KS: Writing, reviewing, and editing. **HN:** Supervision, **CN, DS, YT, SS, YH:** directly and substantively managed this patient, collected data, and drafted and revised this manuscript. **SK:** Supervision. **MH, HJ:** Image analysis using 4D flow MRI.

All authors were involved in reviewing the final draft of the manuscript. All authors have made a significant contribution to preparing the case report.

ACKNOWLEDGMENTS

None.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

CONSENT

The patient has given written informed consent for the publication of this case report

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All data regarding this case has been reported in the manuscript. Please contact the corresponding author if you are interested in any further information.

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Figure legends

Fig 1. (A) 3D-CT revealed an open false with an enlarged false lumen, leading to total arch replacement with FET. (B) 3D CT (C) contrast-enhanced CT showed blood flow in the previously thrombosed false lumen and an enlargement of the false lumen diameter (Fig. 1(B)(C)).

Fig2 4D Flow MRI revealed accelerated flow from the true lumen to the false lumen at the distal end of the Frozen Elephant Trunk (A)axial image (B))3D-view, (C) An increase in wall shear stress at the site where the flow from the true lumen to the false lumen is reached.

Fig, 3 (A) (B) Aortic angiography showed high-velocity blood flow from the true lumen to the false lumen at the distal end of the stent graft. (C) TEVAR was performed for dSINE, resulting in the disappearance of blood flow into the false lumen, and the surgery was concluded (D) Postoperative CT showed thrombosis of the false lumen and a reduction in its diameter (Fig. 3D).

Additional files

Additional file 1 — 4DflowMRI.wmv This video corresponds to Figure 2.

Additional file 2 — angio.wmv This videocorresponds to Figure 3.

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Hosted file

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