Endovascular and hybrid treatments for subclavian artery aneurysms

Ann. Ital. Chir., 2021 92, 6: 709-714
pii: S0003469X21034953

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OBJECTIVE: *This paper retrospectively reviews our experience with endovascular and hybrid treatments for subclavian artery aneurysms (SAA).*
METHODS: *Seventeen patients with SAAs were treated at our center between July 2011 and October 2018. Clinical and follow-up data were extracted from the hospital records and retrospectively reviewed. We routinely use endovascular treatments and stenting or axillary-axillary bypass to treat SAA if vertebral artery blood flow requires restoration. Patients were followed up at 3, 6, and 12 months after their operations and yearly thereafter.*
RESULTS: *Median follow-up was 30.5 months. In 6 patients, the SAAs involved the ipsilateral vertebral artery. Simple coil embolization was performed for 1 patient; endovascular covered stenting and coil embolization for 4 patients; and hybrid treatment for 1 patient. In 11 patients, the SAAs did not involve the ipsilateral vertebral artery. Hybrid treatment was performed for 1 patient; thoracic aortic stent implantation with coil embolization for 1 patient; and covered stent placement in the subclavian artery for 9 patients. Among the 9 patients who were symptomatic at presentation, 8 had relief of symptoms. Leakage was observed in 1 patient, but it stopped spontaneously. Stent occlusion occurred in 33% (3/9), but all were asymptomatic, and no interventions were necessary.*
CONCLUSION: *Endovascular and hybrid treatments appear to be effective for SAAs with few complications and good clinical outcomes.*

KEY WORDS: Covered stent, Coil embolization, Endovascular treatment, Hybrid, Subclavian artery aneurysm

Introduction

Subclavian artery aneurysms (SAAs) account for about 1% of all peripheral aneurysms[1,2], and they are prone to rupture, thrombosis, embolization, and local compression. Prompt treatment, either open surgery or endovascular, is necessary for SAAs with diameters greater than 2.5 cm, especially if the patient is symptomatic. Open surgery is considered risky because of the complicated anatomy around the artery; most surgeons prefer endovascular and hybrid therapies, which are less invasive, allow faster recovery, have a high success rate, and cause few complications.

In this paper, we review our experience with the management of SAAs. We describe the demographic and clinical characteristics of patients with SAAs and present the outcomes of endovascular and hybrid treatments (Table I).

Materials and Methods

PATIENTS

Between July 2011 and October 2018, 17 patients with SAAs were treated at our center. The patients' data were extracted from hospital records and retrospectively reviewed. The 17 patients included 10 men and 7 women, with a median age of 51.3 years (range, 21 to 67 years). Table I shows the baseline characteristics of the patients. One patient had a pseudoaneurysm, and the other 16 had true aneurysms. Twelve aneurysms were on the right side, and 5 were on the left. The diameters ranged from 15 mm to 58 mm, and the diameters of 3 aneurysms were between 15 mm to 25 mm.

Pervenuto in Redazione Ottobre 2020. Accettato per la pubblicazione Novebre 2020
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Endovascular interventions were necessary because of symptoms of chest pain (1 patient) and numbness in upper limbs (2 patients). Nine patients had symptoms at presentation, which included dizziness (3 patients), numbness in the upper limbs (3 patients), cough (2 patients), and chest pain (1 patient). In the other 8 patients, the aneurysms were discovered incidentally during imaging examinations, and the diameters were all greater than 25 mm.

The aneurysms had a high risk of rupture and required treatment. Associated factors/ comorbidities included hypertension (10 patients), coronary artery disease (2 patients), diabetes mellitus (6 patients), hyperlipidemia (6 patients), and smoking (5 patients).

Treatments

In 6 patients, the SAAs involved the ipsilateral vertebral artery. Among these patients, only 1 patient received coil embolization (Fig. 1 A-C); 4 patients received covered stents and coil embolization (Fig. 2 A, B); and 1 patient received a hybrid treatment with coil embolization, right carotid and vertebral artery covered kissing stent placements, and axillary artery-axillary artificial vascular bypass (Fig. 3 A-D).

In 11 patients, the SAAs did not involve the ipsilateral vertebral artery. Among these, 1 patient received hybrid treatment with thoracic aortic stent implantation, coil embolization, and axillary artery-axillary artificial vascular bypass (Fig. 4 A-C); 1 patient received a thoracic aortic stent implantation and coil embolization; and 9 patients received covered stent placement in the subclavian artery (with 1 patient receiving right carotid and subclavian artery covered kissing stents).

Follow-up

Patients were followed up at 3, 6, and 12 months after the operation, and yearly thereafter. The duration of postoperative follow-up ranged from 8 to 80 months (median, 30.5 months). Efficacy of therapy was evaluated by changes in the symptoms and by imaging studies (vascular ultrasound or computed tomography angiography) (Table II).

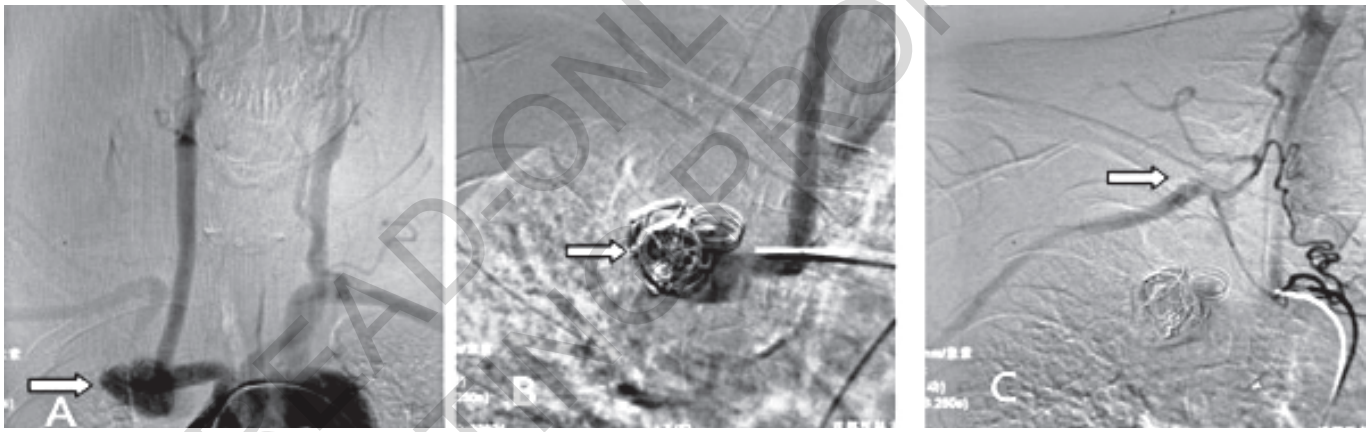

Fig. 1: A) Right subclavian aneurysmal dilatation; B) coil embolization; C) development of collateral circulation

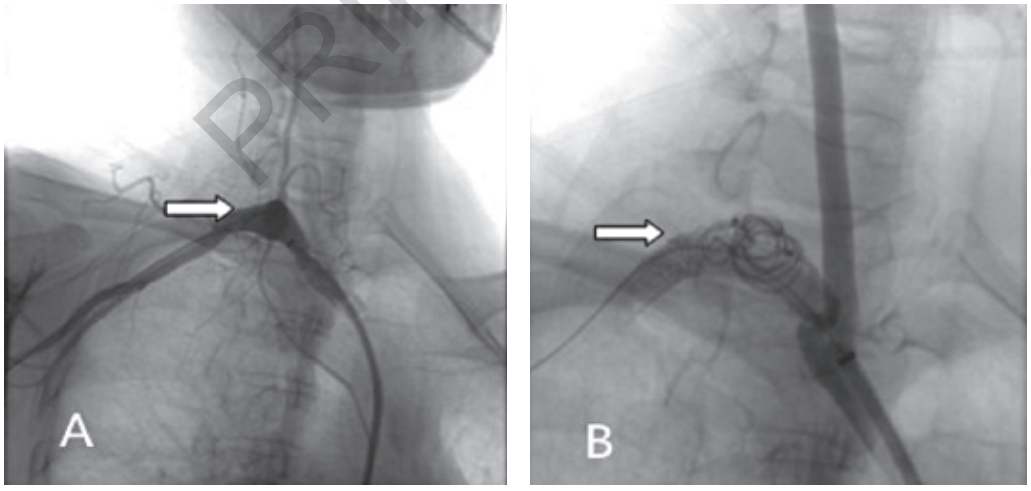

Fig. 2: A) An aneurysm involving the right vertebral artery; B) coil embolization and covered stenting

Table I - *Baseline clinical characteristics*

Characteristic	Median (range) or N
Age, yr	21–67 (51.3)
Male/female	10/7
Clinical manifestations	9
Giddiness	3
Chest pain	1
Numbness and pain in upper limb	1
Numbness in upper limb	2
Cough	2
Associated factors/comorbidities	
Diabetes	6
Hypertension	10
Coronary heart disease	2
Hyperlipidemia	6
Smoking	5
Takayasu arteritis	1
Subclavian artery dissection	1
Aneurysm side, left/right	5/12
Aneurysm size, mm	15–58 (32.1)
Involving the ipsilateral vertebral artery	6

Table II - *Summary of treatments and outcomes in our series*

Therapy methods and follow-up	N
Aneurysm involving the ipsilateral vertebral artery	6
Embolization	1
Stenting combined with embolization	4
Vertebral and common carotid artery stent, coil embolization, and axillary–axillary artificial vascular bypass	1
Aneurysm not involving the ipsilateral vertebral artery	11
Simple covered stent	9
Thoracic artery stent, coil embolization, and axillary–axillary artificial vascular bypass	
Thoracic artery stent and coil embolization	1
Clinical manifestation after operation	1
Symptoms relieved	8/9
No change	1/9
Acute cerebral infarction	1
Follow-up, months, median (range)	30.5 (8–80)
Stent occlusion	3
Chronic cerebral infarction	1

Results

The technical success rate was 100%. Table II shows the therapeutic methods used and the final outcomes. Among the 9 patients with symptoms at presentation, 8 had relief of symptoms after treatment; 1 patient (with upper-limb numbness) had no obvious change after treatment. Among those without symptoms at presentation, 1 patient (with a right-sided SAA) developed restlessness, slurring of speech, and left upper-limb weakness after treatment with a covered stent implantation, and angiography revealed a partial obstruction of the right middle cerebral artery. Carotid artery catheter-directed thrombolysis was performed, and all symptoms subsided. Leakage was observed in 1 patient, but it resolved spontaneously and was no longer evident at follow-up 3 months after the operation. Stent occlusion occurred in 3 asymptomatic patients (at 8 months, 11 months, and 1 year after surgery), but no interventions were undertaken.

Discussion

Subclavian artery aneurysms are extremely rare and are usually secondary to trauma (including iatrogenic trauma), atherosclerosis, or thoracic outlet syndrome;[1,2] patients are often asymptomatic. Complications include rupture, hemorrhage, and thrombosis in the aneurysm cavity.[3] Large aneurysms may compress adjacent structures and cause chest urgency, dyspnea, dysphagia, cough, and numbness of the upper limbs [4].

Open surgery and endovascular procedures are the available treatment methods. While aneurysms located in the second or third part of the subclavian artery can be accessed via a supraclavicular incision, intrathoracic subclavian aneurysms require a thoracotomy, which is associated with significant perioperative morbidity and mortality. Most experts, therefore, prefer endovascular treatment or hybrid repair [5-10], although, due to the rarity of the disease, no large case series have been published. A retrospective study by Gao [11] reported good clinical outcomes in nine cases of SAA treated by the endovascular approach.

Endovascular treatment may be with coil embolization and/or stent implantation, depending upon the location, shape, and size of the aneurysm. There is a risk of posterior circulation ischemia or cerebral infarction if the coil embolization or covered stent occludes the opening of the vertebral artery. Posterior circulation ischemia accounted for about 20%-25% of ischemic strokes, and it has been an important cause of disability and mortality.[12] Therefore, prior to therapy, the bilateral vertebrobasilar arteries should be assessed by vascular ultrasound and angiography. The method of endovascular treatment should be selected according to whether or not the vertebral artery opening is involved.

If the SAA does not involve the vertebral artery or if the vertebral artery is nondominant, posterior cerebral circulation will not be compromised by the sealing of the vertebral artery. Fig. 1 shows a right-sided SAA without involvement of a nondominant ipsilateral vertebral artery. The aneurysm cavity was embolized with a simple coil (MWCE-35, Cook Incorporated, Spencer, Indiana, United States [US]). Fig. 2 shows a right-sided SAA with a right subclavian artery steal syndrome. Two

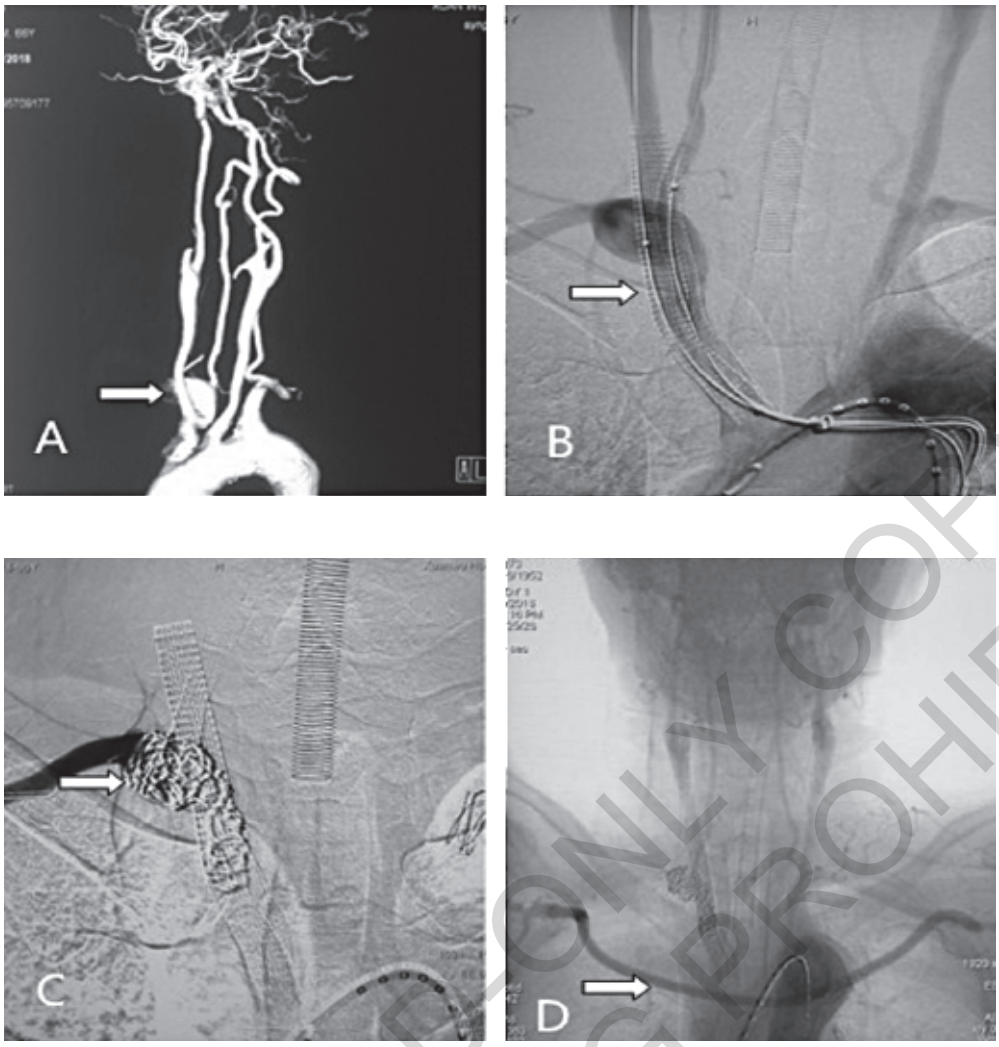

Fig. 3: A) An aneurysm involving the right vertebral artery; B) Right carotid and vertebral artery covered kissing stent placement; C) Coil embolization; D) Angiography after axillary-axillary artery bypass grafting shows disappearance of the right subclavian aneurysm cavity, with good blood flow in the right cervical and vertebral arteries and the artificial vascular bypass.

covered stents (Viabahn, W. L. Gore & Associates, Inc., Newark, Delaware, US) and coil embolization were used to close the aneurysm cavity. In our cohort, 4 patients with SAAs involving vertebral arteries were treated with a covered stent and coil embolization.

If the aneurysm involves the opening of a dominant vertebral artery, the vertebral artery blood flow will require reconstruction. Fig. 3 shows a right-sided SAA with the vertebral artery originating from the aneurysm cavity. The diameter of the aneurysm was 34 mm, and two covered stents (6-10 mm, 9-10 mm, Viabahn, W. L. Gore & Associates, Inc., Newark, Delaware, US) were placed in the right vertebral artery and the common carotid artery, respectively. Coil embolizations were also performed in the aneurysm cavity and the brachial artery. An axillary-axillary artificial vascular bypass was used to rebuild the ipsilateral vertebral artery blood flow. With these measures, posterior circulation ischemia and fatal cerebral infarction were avoided.

The vertebral artery can be retained if there is no involvement with the aneurysm and the distance from the opening of the subclavian artery is greater than 1 cm. The covered kissing stent can be placed in the innominate artery if the distance from the aneurysm neck to the subclavian artery opening is less than 0.5 cm or the stent landing zone is too short. In our cohort, 9 patients were only treated with covered stent implantation to cover the aneurysm.

The aneurysm at the origin of an aberrant subclavian artery is a rare congenital vascular anomaly resulting from anomalous aortic arch development; it is often associated with Kommerell diverticulum [13-15]. This aneurysm cavity should be sealed by an endovascular stent implantation, and vertebral artery blood flow on the affected side should be reconstructed. Figure 4 shows a left-sided SAA with a diameter of 27 mm. Due to the wide base of the aneurysm, the 36-200 mm Valiant Captivia covered stent (Medtronic, Inc., Ireland) could not successfully pass the lesion segment. Attempts to grab the superhard guidewire with the snare also failed. Finally, a 37-200 mm Gore Excluder covered stent (W. L. Gore & Associates, Flagstaff, Arizona, US) was used to block the aneurysm cavity. This was followed by coil embolization and an axillary-axillary artificial vascular bypass.

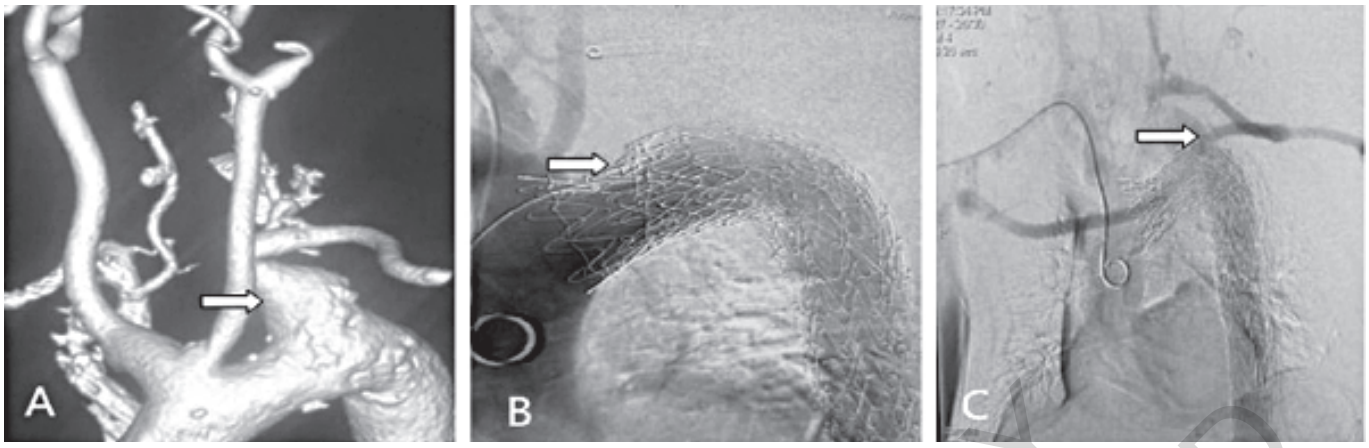

Fig. 4: A) Computerized tomography angiography shows a subclavian artery aneurysm; B) Gore 37–200-mm covered stent implantation; C) Angiography after axillary-axillary artery bypass grafting shows disappearance of the aneurysm cavity and good blood flow in the left vertebral and subclavian arteries and the artificial vascular bypass.

Angiography confirmed the disappearance of the aneurysm cavity and restoration of good blood flow in the left vertebral artery, left subclavian artery, and the artificial vascular bypass.

The ipsilateral vertebral artery blood supply was not preserved in 5 patients in our cohort because the blood supply was not dominant. One patient was treated with a simple coil embolization; and 4 patients were treated with a VIABAHN covered stent placement and coil embolization to seal the subclavian aneurysm cavity and the involved vertebral arteries.

Ipsilateral vertebral artery blood supply was preserved in 11 patients. A covered stent was used in nine patients to seal the subclavian aneurysm and preserve the blood supply of the ipsilateral vertebral artery. One patient was treated with a thoracic aortic covered stent implantation and an axillary-axillary artificial vascular bypass; and 1 patient was treated with thoracic aorta covered stents and a coil embolization (Table II).

One patient in our cohort developed restlessness, slurred speech, and weakness of the upper-left limb after a covered stent implantation in the right-sided SAA. Angiography revealed local infarction of the right middle cerebral artery branch. The patient's symptoms disappeared after a catheter-directed thrombolysis with urokinase.

The right subclavian artery and the right carotid artery share the same trunk, and plaque or thrombus dislodged by a guidewire and catheter in the right subclavian artery can easily enter the right internal carotid artery and cause catastrophic consequences. The operation should, therefore, be performed gently and carefully. The technical success rate was 100% in our cohort. Postoperative angiography showed immediate disappearance of the aneurysm in 10 patients. A Type I endoleak was found in 1 patient, but it had disappeared by follow-up by 3 months after the procedure. Subclavian artery stent occlusion was seen in a patient with Behçet disease at follow-up, 1 year after treatment; another 2 patients with right SAAs also had stent occlusions (at 8 and 11 months). However, none of these patients had any symptoms, and no further interventions were undertaken.

Conclusion

Endovascular and hybrid procedures appear to be safe and effective treatments for SAA and are necessary for symptomatic patients who have aneurysms with diameters less than 25 mm. Endovascular or hybrid treatment is also necessary for SAAs with diameters greater than 2.5 cm. The method of treatment should be selected according to the location, size, and shape of the aneurysm, with the main goal being to preserve vertebral artery blood flow. Further studies are necessary to determine the long-term effects of these treatments.

Riassunto

Studio retrospettivo della nostra esperienza con interventi endovascolari e ibridi per il trattamento degli aneurismi dell'arteria succlavia (SAA).

Lo studio comprende 17 pazienti con SAA trattati presso il nostro centro tra luglio 2011 e ottobre 2018. I dati clinici e di follow-up sono stati estratti dalle cartelle cliniche e rivisti retrospettivamente. Abitualmente adottiamo tecniche endovascolari e stent, o bypass ascello-ascellare per trattare SSA se si richiede il ripristino del flusso sanguigno dell'arteria vertebrale.I pazienti trattati sono stati seguiti a 3, 6 e 12 mesi dopo l'operazione e successivamente ogni anno.

RISULTATI: il follow-up è stato in media di 30,5 mesi. In 6 pazienti, gli SAA coinvolgevano l'arteria vertebrale omolaterale, ed in uno di essi è stata eseguita la semplice embolizzazione con spirale; in 4 pazienti si è pro-

ceduto con embolizzazione con spirale e stent endovascolare rivestito; in un paziente si è adottato un trattamento ibrido.
In 11 pazienti, gli SAA non coinvolgevano l'arteria vertebrale omolaterale. Il trattamento ibrido è stato eseguito per 1 paziente; un impianto di stent aortico toracico con embolizzazione a spirale in 1 paziente; il posizionamento di stent rivestito nell'arteria succlavia per 9 pazienti. Tra i 9 pazienti che erano sintomatici alla presentazione, 8 hanno avuto sollievo dai sintomi. Una filtrazione emorragica è stata osservata in 1 paziente, ma si è interrotta spontaneamente. L'occlusione dello stent si è verificata nel 33% (3/9), ma tutti sono rimasti asintomatici e non sono stati necessari ulteriori interventi.
CONCLUSIONE: i trattamenti endovascolari e ibridi sembrano essere efficaci per gli SAA con poche complicazioni e buoni risultati clinici.

Acknowledgements

We would like to acknowledge the hard and dedicated work of all the staff that implemented the intervention and evaluation components of the study.

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