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Initial Experience with Endoscopic Saphenous Vein Harvesting for Coronary Artery Bypass Grafting in Chinese Patients

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ABSTRACT

Objective: We aimed to investigate the initial experience of endoscopic vein harvesting (EVH) for coronary artery bypass grafting (CABG) in Chinese patients.

Methods: Forty patients scheduled for isolated CABG were prospectively randomized into an EVH group (n = 20) and an open vein harvesting (OVH) group (n = 20). Clinical data were collected, and all of the vein grafts were assessed by macroscopic appearance, histologic quality (endothelial integrity), and functional characteristics of endothelial nitric oxide synthase.

Results: The 2 groups were similar with respect to hospital mortality (EVH group, 0; OVH group, 1; $P = 1$). There were no postoperative myocardial infarctions in either group and no deaths or reinterventions in either group during the follow-up period. Harvesting times in the 2 groups were similar (EVH, 12.15 ± 2.32 min; OVH, 12.55 ± 2.11 min; $P = .571$). Three patients in the EVH group were converted to a partly open or skin-bridge technique. Electrocautery at least 2 mm distal to the origin of the side branch was the safety margin.

Conclusions: The use of EVH in Chinese patients was not related to adverse events and may be safely used for CABG procedures. Preoperative duplex mapping, systemic heparinization before harvesting, minimal surgical manipulation, and sectioning of side branches at least 2 mm distal to the origin may help improve the quality of vein grafts harvested with EVH and maximize the benefit of this less-invasive technique.

INTRODUCTION

Although numerous reports about endoscopic vein harvesting (EVH) have been published [Lumsden 1996; Allen 1998; Eagle 2004; Allen 2005; Nickum 2005], there are few reports of the use of this technique in an Asian population [Vaidyanathan 2008], which is technically more challenging than in Western patients because of the more delicate veins, less subcutaneous fat, and a different coagulation status. Most importantly, as with every new technique, we have seen success and frustrations with EVH techniques. This approach is somewhat controversial at present because the investigators of the PREVENT IV trial (Project of Ex Vivo Vein Graft Engineering via Transfection) found EVH to be an independent predictor of decreased saphenous vein graft patency at 1 year and to be associated with worse clinical outcomes. The aspect of EVH responsible for the worse outcome is not yet known, however, further investigations are needed [Lopes 2009]. Rousou et al also reported disappointing results regarding the impact of EVH on the structure and function of the saphenous vein [Rousou 2009] after the many other excellent results had been described [Lumsden 1996; Allen 1998; Eagle 2004; Allen 2005; Nickum 2005].

We describe our preliminary experience with EVH for coronary artery bypass grafting (CABG) in Chinese patients. Our hypothesis was that the poor clinical outcomes with EVH were associated with intraluminal clotting, with avulsion in the vein caused by the small side branches being torn during dissection by the conical dissecting cannula (CDC), with thermal injury to the parent trunk caused by the bipolar electrocautery scissors, and with the surgical manipulation and damage from the cold and dry CO_2 applied to the vein.

PATIENTS AND METHODS

Between July 2009 and September 2009, we prospectively randomized 40 patients scheduled for isolated CABG at our department into 2 groups (EVH and open vein harvesting [OVH]) in order to evaluate the EVH technique. The study was approved by our institutional ethics committee on human research, and informed consent was obtained from the patients.

Preoperative Duplex Venous Mapping

Routine preoperative Doppler venous mapping was carried out in all cases to detect deep venous thrombosis, varicose veins, and thrombosis in the greater saphenous vein. It was used to locate both the main trunk and the large collateral branch on the skin; to find the diameter, the intima, and the lumen of the vein; and to identify a double venous system when present.

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Operative Technique

One surgeon (H. Wu) who was trained and experienced in EVH harvested all of the vein grafts. All EVH procedures were performed with VasoView Endoscopic Vessel Harvesting System 5 (Guidant-Maquet Cardiovascular, San Jose, CA, USA). After a single 5000-IU intravenous bolus of heparin was administered, a 2-cm incision that had been marked preoperatively by duplex mapping was made above and below the knee. After the anterior and posterior planes of the vein were maximally dissected with scissors toward the groin in the fascial canal, the blunt-tip trocar port was carefully inserted into the incision, and air was injected into the balloon to seal the tunnel and avoid damaging the vein beneath the trocar. CO_2 insufflation was used for visualization in the tunnel, dissection, and hemostasis. The CDC was used to gently dissect the great saphenous vein from the surrounding tissue, with great care taken to keep the conical tip away from the adventitia of the vein. If possible, preservation of the perivascular tissue was preferred; all of the side branches encountered during advancement of the CDC were left for dissection later with small bipolar scissors. Once the vein was mobilized in the middle of the canal, the small collateral branches were coagulated with bipolar electrocautery (Aesculap GK050; Aesculap AG, Tuttlingen, Germany) at 20 W for 2 seconds at least 2 mm distal to their origin and then divided with the bipolar scissors. The distal ends of side branches >3 mm were clipped after "grasp and cut" via a 3- to 4-mm stab incision that had been marked preoperatively by duplex mapping. Short branches or branches very close to the skin were also managed in this manner to ensure hemostasis and to avoid thermal injury to the main trunk and skin. The proximal end of the saphenous vein was excised through a stab incision at the groin. The bipolar electrocautery instrument was reintroduced into the tunnel for meticulous hemostasis after the vein had been removed, the incision was closed in the usual fashion without drainage, and compression dressings were applied.

Table 1. Baseline Characteristics of the Patients*

	EVH Group (n = 20)	OVH Group (n = 20)	*P*
Age, y†	58.95 ± 10.16	64.45 ± 7.44	.058
BMI, kg/m^2†	26.27 ± 2.60	25.23 ± 2.87	.237
Follow-up, d†	101.30 ± 52.80	121.50 ± 44.91	.200
Female/male sex, n	1/19	2/18	1.000‡
Diabetes, n	7	5	.490
Hypertension, n	8	7	.744
LVEF <50%, n	3	2	1.000‡

*The numbers of vein grafts used per patient in the 2 groups were similar (Figure 1). EVH indicates endoscopic vein harvesting; OVH, open vein harvesting; BMI, body mass index; LVEF, left ventricular ejection fraction.

†Data are expressed as the mean ± SD.

‡Fisher exact test.

All patients underwent off-pump CABG performed by the same surgeon (H. Wang). Octopus 4.3 tissue stabilizers (Medtronic, Minneapolis, MN, USA) were used in all cases. The left internal mammary artery was anastomosed to the left anterior descending artery in all patients. Vein grafts were anastomosed to the diagonal branch, obtuse marginal, and posterior descending arteries in accordance with the coronary artery angiogram and intraoperative findings. The proximal anastomosis was routinely performed before the distal one to aid in early reperfusion, and a section of vein that would not be needed for bypass was removed for appropriate processing just before the distal anastomosis was performed.

In OVH, the vein was obtained through a long linear incision in the leg by means of a standard sharp-dissection technique with fine scissors and ligation of the side branches with metal clips.

The macroscopic quality of the veins procured with both techniques was assessed as good, fair, or poor by the primary surgeon.

Preparation of Vein Segments

The vein segments were fixed in 4% formaldehyde for light microscopy assessment and in 2.5% glutaraldehyde for scanning electron microscopy (SEM). Immunohistochemistry methods were used to stain samples used for endothelial nitric oxide synthase (eNOS) measurement; stained samples were then assessed with computer image-analysis software.

A pathologist who had been blinded to the harvesting methods assessed the quality of the vein segments by light microscopy and SEM.

Data Collection

Data were collected from the database of our department. Patients were followed up via direct contact during their

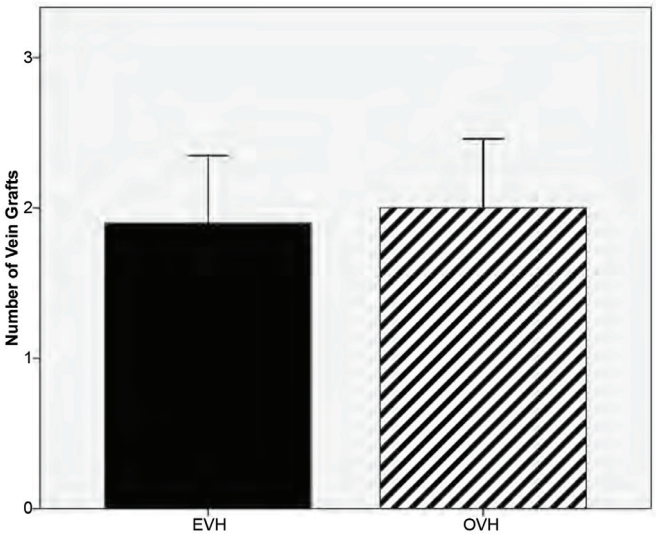

Figure 1. Number of vein grafts used per patient in the 2 groups. *P* = .489. EVH indicates endoscopic vein harvesting; OVH, open vein harvesting.

outpatient clinic visits and by telephone. Data are expressed as mean ± SD. Categorical data were analyzed with the chi-square test, and the Fisher exact test was used for small sample sizes. A *P* value of .05 was considered statistically significant. Statistical analyses were performed with SPSS for Windows (version 17.0.0; SPSS, Chicago, IL, USA).

RESULTS

Table 1 summarizes the baseline profiles of the patients in the 2 study groups. No significant differences between the 2 groups were noted.

Saphenous vein thrombosis was found in 1 patient in the OVH group by preoperative Doppler venous mapping, and the vein grafts were harvested from the other leg. Double venous systems were found by preoperative Doppler venous mapping in 2 patients in the EVH group. A Y graft was harvested in one of the patients, and the larger and deeper system was harvested in the other patient. Preoperative Doppler venous mapping revealed no saphenous vein varicosis in either cohort.

Conversion to a partially open or skin-bridge technique was necessary in the EVH group for 3 patients with slim legs.

Tunnel hematoma was experienced on the third postoperative day in 2 patients in the EVH group (Table 2); revision was carried out, with the hematoma evacuated by suction through the 2-cm incision previously used. After that, branches larger than 3 mm were controlled with metal clips via stab incisions; no hematoma was found in the EVH group thereafter.

Wound healing was good in both groups; no leg wound infection was encountered in either group.

Pain, edema, numbness, and tightness were more common during the first postoperative week in the OVH group (Table 2). No patients complained of pain in the leg incision in the EVH group except for 2 patients with tract hematoma (Table 2).

A male patient in the OVH group with an old myocardial infarction died on the fourth postoperative day from ventricular fibrillation refractory to medical therapy. No postoperative myocardial infarction occurred in either group. No patient died or underwent reintervention, and angina did not recur during the follow-up period (111.4 ± 7.8 days).

No differences between the 2 groups were noted regarding the macroscopic quality of the veins (Table 3).

Table 2. Mortality and Complications*

	EVH	OVH	*P*
Mortality	0 (0%)	1 (5%)	1†
Edema	2 (10%)	10 (50%)	.006‡
Pain	2 (10%)	13 (65%)	0‡
Hematoma	2 (10%)	0 (0%)	.478†

*EVH indicates endoscopic vein harvesting; OVH, open vein harvesting.
†Fisher exact test.
‡Pearson chi-square test.

DISCUSSION

In our initial experience, EVH may be a valuable graft-harvesting method for CABG in Chinese patients.

EVH is widely accepted by many centers and patients, because conventional OVH is associated with significantly more comorbidity [Lumsden 1996]. Despite the reported benefits [Lumsden 1996; Allen 1998; Eagle 2004; Allen 2005; Nickum 2005], however, the technique and technology still need to be improved, because a possible relationship between EVH and a worse graft patency was recently found in the PREVENT-IV trial [Lopes 2009].

One of our authors (H. Wu) underwent EVH training at the German Heart Institute in Berlin; however, we were aware of the difference between Western and Eastern patients when he started EVH in China. Most patients in China were younger with a low body mass index and less subcutaneous fat. The tissue was quite dense, creation of space was more difficult, and, in contrast to Western patients' hypercoagulable state, hemostasis was more difficult in the tunnel during EVH. Below we describe our preliminary experience with EVH for CABG in Chinese patients and elucidate the problems and measures necessary to improve the quality of the vein harvested with EVH.

Clearly, graft patency is imperative for patients undergoing CABG. However, intraluminal clot formation in EVH veins, the significantly greater surgical manipulation of the vein during endoscopic harvesting, the thermal injury occurring when electrocautery is used near the vein, and the cold and dry CO_2 applied to the vein all may contribute to a suboptimal graft patency and a worse clinical outcome.

Intraluminal clotting within the saphenous vein is well recognized as an adverse effect of EVH [Brown 2007]. Sealed tunnel and CO_2 insufflations used to facilitate visualization cause stagnation of blood within the vein, yet anticoagulation

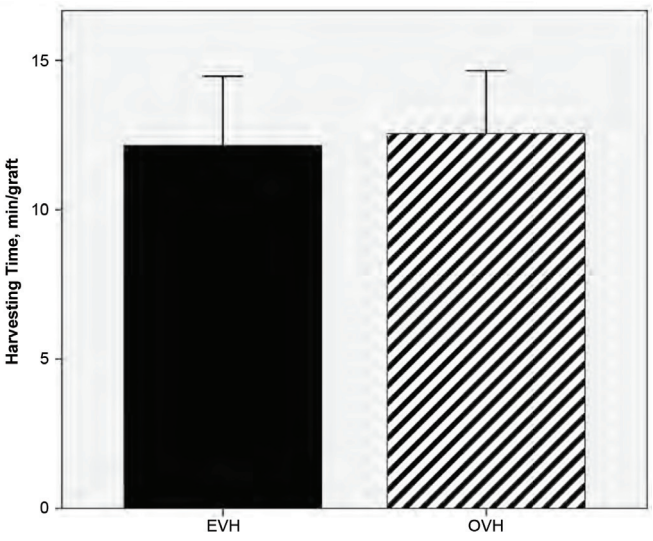

Figure 2. Harvesting time. Harvesting times (from skin incision to skin closure) in the 2 groups were similar (*P* = .571). EVH indicates endoscopic vein harvesting; OVH, open vein harvesting.

Table 3. Macrographic Quality of the Veins*

	Good	Fair	Poor
EVH, n	16	4	0
OVH, n	17	3	0

*P = 1, Fisher exact test. The lengths of tissue damage at the bipolar electrocautery site were 1.16 ± 0.19 mm on the side branches in the endoscopic vein harvesting (EVH) group (Figure 3). OVH indicates open vein harvesting.

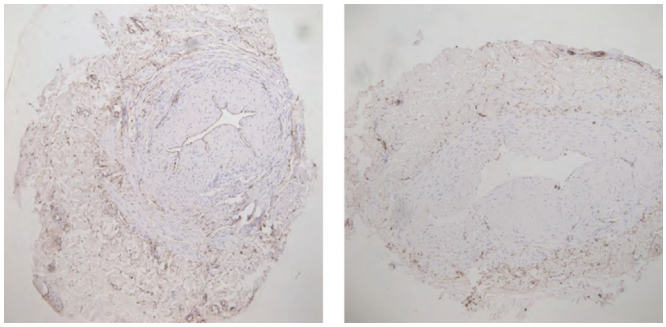

Figure 3. Slides showing tissue without thermal damage at 2 mm proximal to the sectioning site on the side branches in the endoscopic vein harvesting group.

is not usually given until after harvesting. The majority of centers participating in the PREVENT-IV trial did not use systemic preheparinization, and that fact may help to explain the disappointing vein graft patency rates that were seen with conduits procured with EVH. Our current daily practice is to administer heparinization with a bolus of 5000 IU before initiation of EVH [Brown 2007].

Prevention of intraoperative injury to the vascular endothelium is of primary importance in maintaining viability and long-term patency of saphenous vein grafts in CABG patients. This injury may occur at the time of harvest, because of the blunt surgical trauma and stretching [Zilla 1993; Sellke 1997; Verrier 1997].

Tearing of side branches and avulsion may originate from dissection with the CDC, especially in the lower one third of the thigh, where the tissue is quite dense and tunnel creation with the CDC is difficult. That may bring more tension to bear on the side branches, and endothelial damage or denudation of endothelial cells may activate both the intrinsic and extrinsic pathways of the coagulation cascade, owing to the exposure of basement membrane collagens and the subendothelial matrix [Rang 1995]. Endothelial injury can also form an initiation site for the formation of later-stage atheromas and decrease the patency rate [Zilla 1993].

We modified the EVH technique by only gently dissecting the anterior and inferior planes of the vein with the CDC. Extreme care was taken to minimize tension on any collateral branches, and damage to the adventitia was avoided by keeping the tip of the cannula away from the vein and preserving perivascular tissue. We avoided dissection of collateral branches with the CDC because the large cannula may exert too much tension on the ostia of side branches, where most avulsion and endothelial cell denudation occur. Instead, the bipolar scissors were used to dissect the left and right side planes, where we used the quite small bipolar scissors to divide the many collateral branches together with fat by creating windows near the collateral branches without adding much tension. This method produced less tearing of small side branches. We also propose that a new miniature device with a smaller CDC be developed for this subgroup of lean patients with a lower body mass index and slimmer legs, because less subcutaneous fat and smaller spaces exist around the vein, especially for a vein with a thin wall. To harvest the vein grafts from the upper two-thirds of both thighs is another choice, rather than from the calf. We also encountered superficial veins more frequently in the population of lean Eastern patients, which may explain the relatively high rate of conversion to a partial OVH or skin-bridge technique in our group. Others have also made this observation [Vaidyanathan 2008].

The macrographic structure of the veins prepared with the EVH technique was well preserved in this study because of our understanding of the blunt trauma and stretch associated with blunt dissection.

Higami et al developed a new technique that uses an ultrasonic scalpel to skeletonize the internal thoracic artery. The temperature produced by the ultrasonic scalpel in the tissue is approximately 80°C, compared with >300°C with electrocautery [Higami 2000a]. These authors' histologic study confirmed that the ultrasonic scalpel applied to branches >1 mm away from the internal thoracic artery itself did not cause any endothelial injury [Higami 2000b].

The low-energy bipolar cautery setting we used in this study produces less smoke, lowers the risk of thermal injury, and provides better coagulation of the side branches of the vein before section. Using the bipolar electrocautery scissors very carefully so as not to touch the vein itself was the key to protecting the parent trunk from thermal injury. We applied the electrocautery instruments on the side branches at least 2 mm away from the main trunk when dividing them. Neither SEM nor the light micrography study revealed any endothelial cell injury in any part of the vein trunk.

The fact that 2 patients in the EVH group developed hematoma suggests, however, that the lower energy (20 W) was not sufficient to ensure hemostasis in the tunnel, although it was safer for the vein. Thereafter, we checked the tunnel again after the vein was harvested, and the larger branches were managed by the use of metal clips via a stab incision.

The functional viability of the saphenous vein was assessed by evaluating eNOS, which is responsible for the synthesis of nitric oxide. The similarity in eNOS expression in the 2 groups is evidence that graft harvesting by EVH at least produces similar endothelial damage in grafts. The preserved endothelial function should be investigated in long-term follow-up studies.

The histologic findings in this study showed that saphenous veins harvested with the EVH technique retained their architecture and the vein's endothelium, as well as eNOS expression, which are important for improving the long-term graft patency rate.

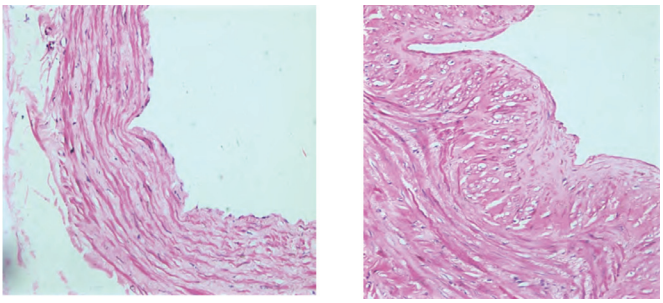

Figure 4. Light microscopy of the wall architecture of vein grafts (hematoxylin and eosin staining). No differences between the 2 groups were noted.

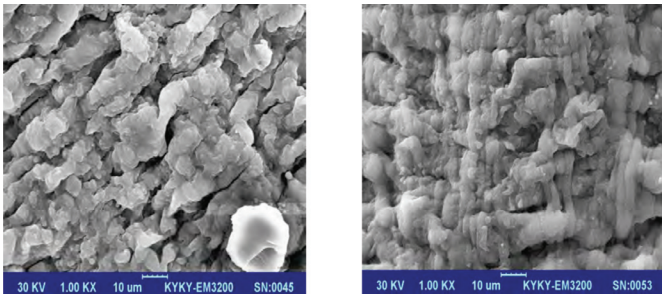

Figure 5. Scanning electron microscopy of endothelial cells of vein grafts; no differences between the 2 groups were noted.

The use of preoperative Doppler mapping in our protocol diminished unnecessary incision and dissection in the 2 groups when the vein that could not be used was found before the operation. It also saved time in locating the vein and the side branches.

Greater patient satisfaction was observed in the EVH group because of significantly less pain and edema.

No wound infection occurred in either group, perhaps because of the younger ages of the patients and the small number of patients with diabetes who were enrolled.

This study is limited by the relatively small number of patients, which did not allow us to draw any definite conclusions. Our findings confirmed the preservation of the endothelial cell lining of the vein at the cellular level; however, ultrastructural effects that could potentially be harmful to the vein harvested with EVH were not evaluated in this study. A larger randomized study of mid- to long-term outcomes that will investigate more-sensitive markers of endothelial function is ongoing at our hospital.

In conclusion, EVH is a safe alternative to OVH when efficacious strategies are strictly followed, especially during the relatively longer learning curve; there will be more refinements as time passes. More research is required to elucidate the mechanisms behind the possible detrimental effects on long-term patency. Further evolution of the technology and the techniques may maximize the benefit from this less-invasive method of vein harvesting and allow us to adapt it to the needs of Chinese patients.

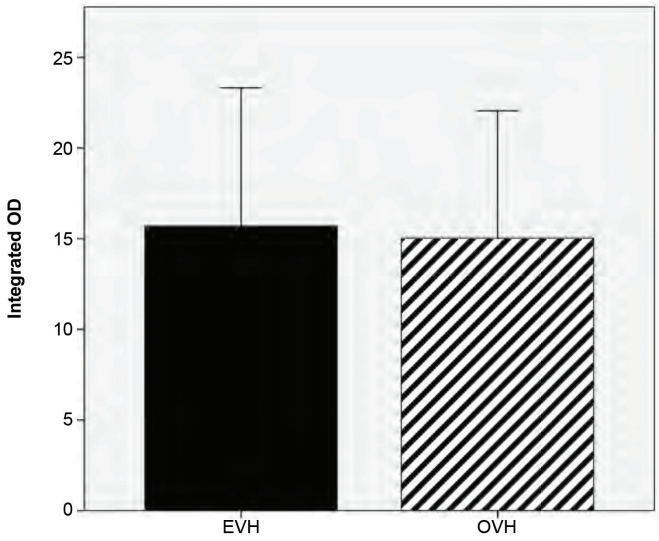

Figure 6. Endothelial nitric oxide synthase (eNOS) activity in the endoscopic vein harvesting (EVH) and open vein harvesting (OVH) groups. eNOS integrated optical density (OD) data are presented as the mean and SD; the 2 groups were not significantly different.

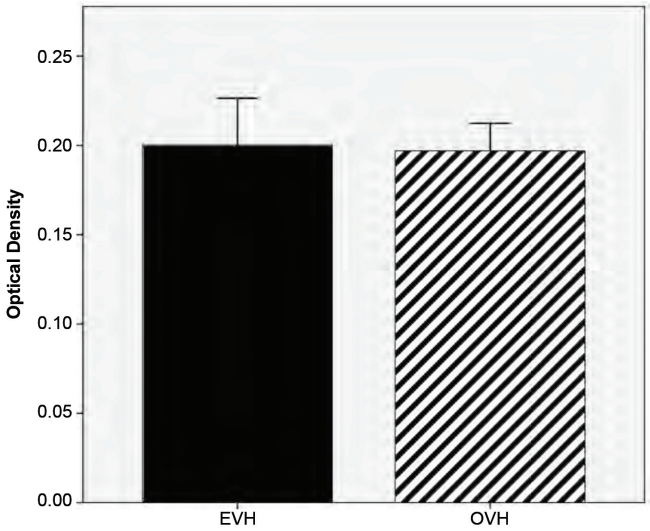

Figure 7. Endothelial nitric oxide synthase activity in the endoscopic vein harvesting (EVH) and open vein harvesting (OVH) groups. eNOS optical density data are presented as the mean and SD; the 2 groups were not significantly different.

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