

Perioperative outcomes and graft patency in coronary artery bypass grafting (CABG) after no-touch saphenous vein harvesting: A single-center exploratory study

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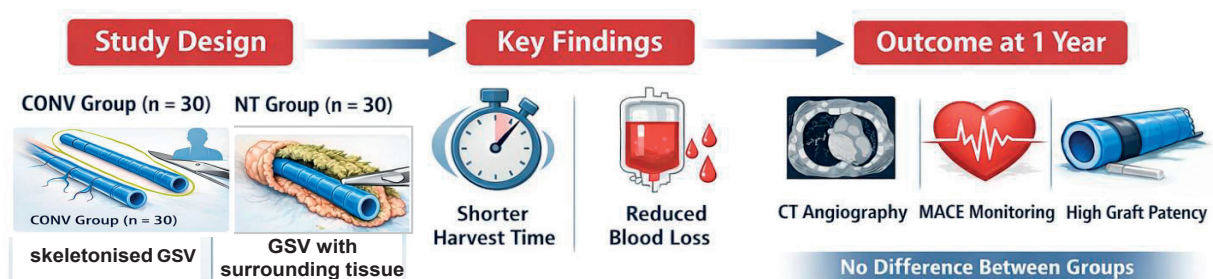
Background. The no-touch (NT) technique for saphenous vein harvesting aims to preserve vascular integrity and improve graft performance in coronary artery bypass grafting (CABG). However, concerns remain regarding wound healing disorders and local complications at the graft harvest site.

Methods. This prospective observational comparative study included 60 consecutive patients undergoing CABG, allocated to conventional saphenous vein harvesting (CONV, n=30) or the NT technique (NT, n=30). Group allocation was based on routine clinical practice and surgeon preference, without formal randomization. The primary outcome was the incidence of wound healing disorders and local complications at the harvest site. Secondary outcomes included perioperative parameters, major adverse cardiovascular events (MACE), and venous graft patency assessed by computed tomography coronary angiography one year after surgery.

Results. Operative time and aortic cross-clamp time were comparable between groups. Shorter graft harvesting time was observed in the NT group (35 ± 7.5 min vs. 43 ± 9.1 min; $P=0.001$), along with significantly reduced perioperative blood loss (15 ± 7 mL vs. 40 ± 12.1 mL; $P<0.0001$). The incidence of subcutaneous hematoma on postoperative day 7 was significantly lower in the NT group (20% vs. 60%; $P=0.003$). No statistically significant differences were found between groups in wound infection rates, MACE, or venous graft patency at one-year follow-up.

Conclusion. The NT technique for saphenous vein harvesting offers relevant perioperative advantages, including shorter harvesting time, reduced blood loss, and fewer early local complications, without adversely affecting operative time, major adverse cardiac events, wound infection, or one-year graft patency.

PERIOPERATIVE OUTCOMES AND GRAFT PATENCY AFTER NO-TOUCH SAPHENOUS VEIN HARVESTING: A SINGLE-CENTER EXPLORATORY STUDY



In this exploratory, small cohort, the no-touch technique was associated with reduced blood loss, and no evidence of large differences in 1-year wound complications or graft patency was observed.

Konecny J. et al., doi: 10.5507/bp.2026.007

Graphical Abstract

Biomedical Papers
https://biomed.papers.upol.cz

Key words: coronary artery bypass grafting, saphenous vein harvesting, NT technique, wound healing complications, graft patency

Received: January 11, 2026; Revised: March 11, 2026; Accepted: March 13, 2026; Available online: March 24, 2026
<https://doi.org/10.5507/bp.2026.007>

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INTRODUCTION AND AIMS

Ischemic heart disease remains one of the leading causes of morbidity and mortality worldwide. Although current treatment strategies are largely palliative, surgical myocardial revascularization remains an effective therapeutic option for patients with advanced coronary artery disease. Coronary artery bypass grafting (CABG) restores blood flow to ischemic myocardial territories by bypassing significantly stenotic coronary arteries.

For more than five decades, the great saphenous vein (GSV), typically used in a reversed orientation, has been one of the most commonly employed conduits in coronary surgery¹. Long-term outcomes of surgical revascularization depend on multiple factors, including graft selection and graft quality. The left internal thoracic artery (LITA) is considered the gold standard for revascularization of the left anterior descending artery, while venous grafts remain widely used for revascularization of other coronary targets². Arterial grafts demonstrate excellent long-term patency, exceeding 90% at 10 years, whereas venous grafts achieve approximately 60% patency during the same period^{3,4}.

Early failure of venous grafts within the first postoperative year may result from technical factors, thrombosis, neointimal hyperplasia, or accelerated atherosclerosis⁵. Beyond the first year, structural changes within the vein graft wall, particularly neointimal hyperplasia and progressive atherosclerosis, represent the dominant mechanisms of graft failure. The harvesting technique, storage conditions, and intraoperative handling of the venous graft significantly influence its morphological and functional integrity and may fundamentally affect long-term patency^{5,6}. Consequently, the primary goal of vein harvesting is to obtain a conduit that is both morphologically and functionally preserved.

The NT harvesting technique, first described by Souza et al., was developed to protect the endothelium and vasa vasorum by harvesting the vein together with its surrounding perivascular tissue. Long-term follow-up studies have demonstrated superior patency of NT-harvested venous grafts compared with conventionally harvested grafts, approaching outcomes observed with arterial conduits⁷. However, concerns have been raised regarding a potentially higher incidence of wound healing complications at the harvest site associated with this technique⁸⁻¹⁰.

Wound healing complications following GSV harvesting represent a common clinical problem in CABG, with reported incidence rates ranging from 1% to 24% (ref. ¹¹⁻¹³). Several strategies aimed at improving venous graft patency have been investigated, including fibrin glue application and external graft support using DacronTM or mesh systems¹⁴⁻¹⁷. Despite advances in graft preservation, the balance between improved graft performance and donor-site morbidity remains clinically relevant.

The primary aim of this prospective comparative study was to evaluate the incidence of wound healing disorders and local complications at the saphenous vein harvest site following the NT technique compared with conventional harvesting. Secondary objectives were to assess periop-

erative parameters, major adverse cardiovascular events (MACE), and early venous graft patency, evaluated by computed tomography coronary angiography one year after surgery.

MATERIALS AND METHODS

The study was designed as a prospective observational comparative study including consecutive adult patients undergoing isolated CABG. Eligible patients were older than 18 years and scheduled for elective CABG performed using cardiopulmonary bypass, with implantation of at least one venous graft to a coronary artery with a target vessel diameter greater than 1.5 mm. Additional inclusion criteria comprised the availability of a suitable great saphenous vein as assessed by preoperative ultrasonography and the provision of written informed consent. Patients were excluded if they underwent reoperation or acute surgery, required concomitant cardiovascular procedures, had a body mass index below 20 or above 35 kg/m². Patients with a BMI < 20 kg/m² were excluded because a lack of subcutaneous fat increases the risk of skin necrosis and wound tension, especially given the wider pedicle dissection required for the NT technique. Additionally, low BMI often indicates frailty or malnutrition, which could independently impair healing and confound the comparison of harvesting outcomes. The upper threshold chosen due to the increased technical complexity of saphenous vein harvesting and the higher risk of harvest-site-related wound complications in morbidly obese patients, insulin-dependent diabetes mellitus or diabetes-related multior-gan complications, advanced peripheral arterial disease (grade III-IV), chronic kidney disease with serum creatinine levels exceeding 200 µmol/L, poor-quality venous grafts according to ultrasonographic assessment, or if they declined participation in the study.

A total of 60 patients meeting these criteria were included. Patients were allocated to either the NT or conventional saphenous vein harvesting group based on routine clinical practice, primarily reflecting the operating surgeon's preferred harvesting technique; no formal randomization was performed. All participants provided written informed consent prior to inclusion in the study. No interventions beyond standard surgical care were introduced.

Thirty patients underwent the NT technique, and thirty patients underwent conventional saphenous vein harvesting (CONV). All patients underwent CABG using cardiopulmonary bypass, with the left internal thoracic artery used for revascularization of the left anterior descending artery and the great saphenous vein used for revascularization of other coronary targets.

All procedures were performed by a single surgeon. Vein harvesting was carried out by surgeons experienced in both harvesting techniques. Preoperative risk factors, perioperative parameters, and harvesting characteristics were prospectively recorded and compared between groups.

Donor-site complications, including wound infection, wound dehiscence, hematoma, peripheral neuropathy, and edema, were assessed during routine follow-up visits at 7 days, 3 months, 6 months, and 12 months postoperatively. Wound dehiscence was defined as a partial superficial separation of the skin edges at the vein harvesting site without involvement of deep tissue layers or graft exposure. One year after surgery, venous graft patency was evaluated using computed tomography coronary angiography. The incidence of major adverse cardiovascular events was obtained from the national cardiovascular registry.

NT harvesting of the GSV

The great saphenous vein was harvested using an open NT technique, preserving the surrounding perivascular tissue. During harvesting, the saphenous nerve was visually identified and gently separated from the vein using a soft vessel loop. Small nerve branches crossing the vein were divided when necessary, while the main trunk of the saphenous nerve was preserved and protected by traction

with the vessel loop away from the vein throughout the harvesting procedure. The harvested grafts, including the surrounding tissue, had an approximate external diameter of 5 mm (Fig. 1 and 2). Hemostasis during vein harvesting was achieved using a harmonic scalpel, which was employed consistently in both study groups, in accordance with routine institutional practice. The harvested venous grafts were gently dilated using systemic arterial pressure generated by the cardiopulmonary bypass circuit (Fig. 3), avoiding manual overdilation.

Coronary anastomoses were performed using standard surgical techniques. The surrounding tissue of the saphenous graft were fixed to the heart in several places with 8-0 polypropylene sutures (Prolene®, Ethicon) to prevent graft rotation and subsequent strangulation of the bypass (Fig. 4).

For comparison, CONV was performed using an open technique with skeletonization of the vein and ligation of side branches, without preservation of the surrounding perivascular tissue.

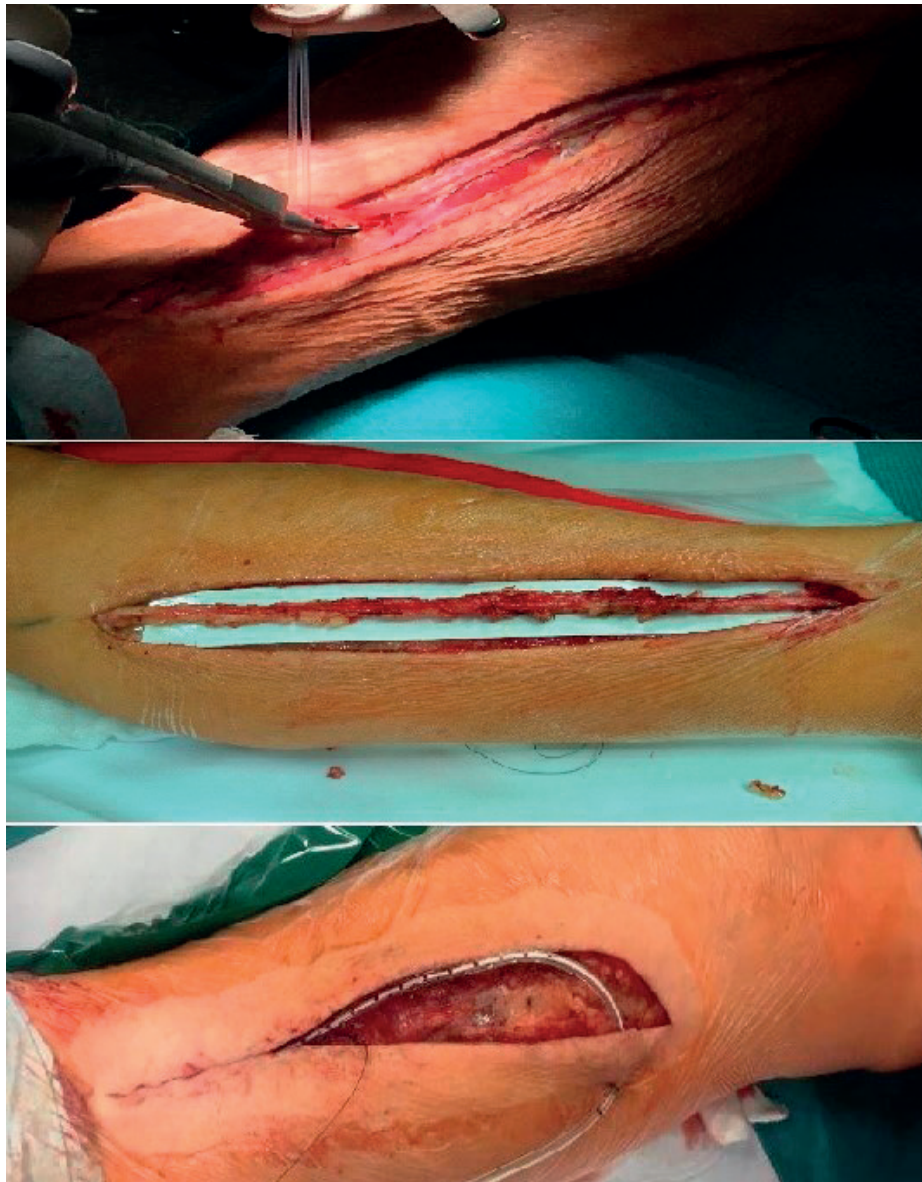


Fig. 1. Venous graft harvesting using the NT method.

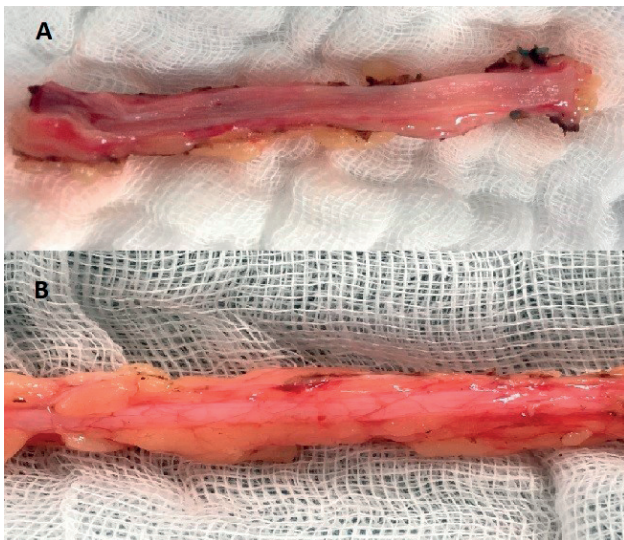


Fig. 2A. View of the endothelium of a vein harvested using the NT technique; **2B.** Detailed view of a graft harvested using the NT method; the vasa vasorum on the surface of the graft is also visible here.

In both groups, surgical drains were removed on the third postoperative day to allow accurate monitoring of postoperative blood loss and to support wound healing.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was reviewed and approved in by the Institutional Ethics Committee of the Faculty of Medicine and Dentistry, Palacký University Olomouc, and University Hospital Olomouc.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics version 23 and TIBCO STATISTICA version 13.4.0.14. Categorical variables are expressed as absolute and relative frequencies and compared using Fisher's exact test. Continuous variables are presented as means $\pm$ standard deviation or median with range, as appropriate. Normality of data distribution was assessed visually and using the Shapiro-Wilk test. Due to non-normal data distribution, between-group comparisons were performed using the Mann-Whitney U test.

Survival analysis was conducted using the Kaplan-Meier method. Given the limited sample size, survival



Fig. 3. Venous graft harvested using the NT method, dilation by systemic blood pressure through the CPB.

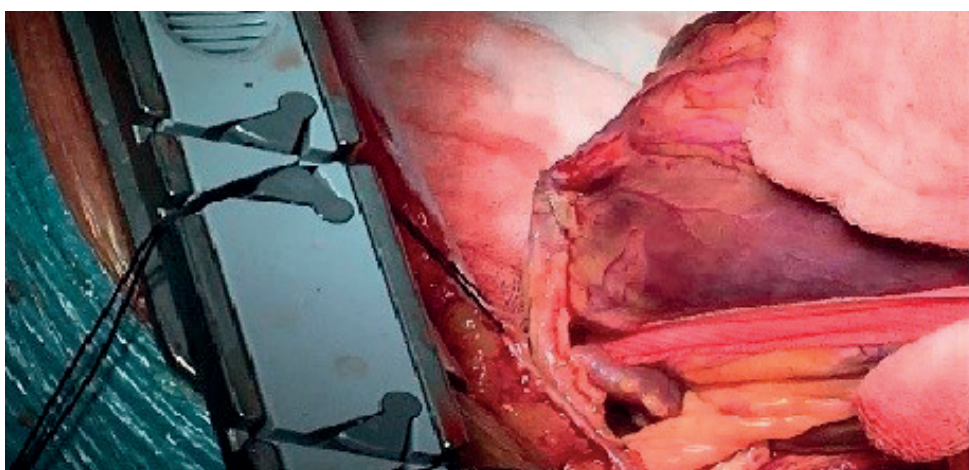


Fig. 4. Graft harvested by using the NT method on the heart.

analyses were considered exploratory. A two-sided *P*-value < 0.05 was considered statistically significant.

RESULTS

The study included 60 consecutive patients who were divided into two groups according to the method of harvesting used for the vein grafts: conventional harvesting (CONV, *n*=30; 8 women and 22 men) and NT harvesting (NT, *n*=30; 6 women and 24 men) between 2017 and 2018. Demographic parameters monitored included age (CONV 69 ± 9 vs. NT 66 ± 8.3 ; *P*=0.859) and body mass index (BMI), which was slightly higher in the CONV group (28.3 ± 2.5 kg/m² vs. 27.3 ± 2.8 kg/m²; *P*=0.037). Comorbidities did not show any statistically significant differences.

The average time of surgery was comparable (CONV 171.5 ± 36.9 min vs. NT 170 ± 32.7 min; *P*=0.617), as was the clamp time (CONV 40 ± 10.2 min vs. NT 42 ± 11.6

min; *P*=0.645). A statistically significant difference was observed in graft harvesting time (CONV 43 ± 9.1 min vs. NT 35 ± 7.5 min; *P*=0.001) and total limb procedure time (CONV 56.5 ± 10.6 min vs. NT 50 ± 8.5 min; *P*=0.002). The NT technique demonstrated lower blood loss, both intraoperatively (CONV 40 ± 12.1 mL vs. NT 15 ± 7 mL; *P*<0.0001) and as reflected by postoperative drainage volume from the harvest site (CONV 90 ± 29.1 mL vs. NT 50 ± 20.4 mL; *P*<0.0001).

The number and location of grafts on the peripheral coronary arteries were comparable between the groups. Complications at the donor site, including infection, dehiscence, hematoma, peripheral sensory neurological deficits, and edema, were monitored (Table 1). In all cases, dehiscence was considered minor (superficial) and managed conservatively with local wound care. No cases required surgical revision or resulted in graft-related complications.

Only the incidence of subcutaneous hematoma on the seventh postoperative day showed a statistically significant decrease in the NT group (CONV 18 vs. NT 6; *P*=0.003). One year after surgery, CT coronary angiography was performed in all patients, and the results were statistically evaluated (Table 2). No significant differences were found between the groups (*P*>0.05).

No statistically significant difference in MACE rates was observed between the groups during follow-up (*P*>0.05; Table 3); however, the study was not powered to detect small or moderate differences in clinical events in this small, low-risk cohort.

Kaplan–Meier survival analysis demonstrated no statistically significant difference in three-year overall survival between the NT and conventional harvesting groups (*P*=0.570; Fig. 5). Survival curves remained largely overlapping throughout the follow-up period, with no evidence of early or late divergence between the groups.

DISCUSSION

The incidence of wound healing disorders after GSV harvesting for surgical myocardial revascularization ranges widely from 1% to 42% (ref.¹⁸). Current clinical

Table 1. Postoperative complications.

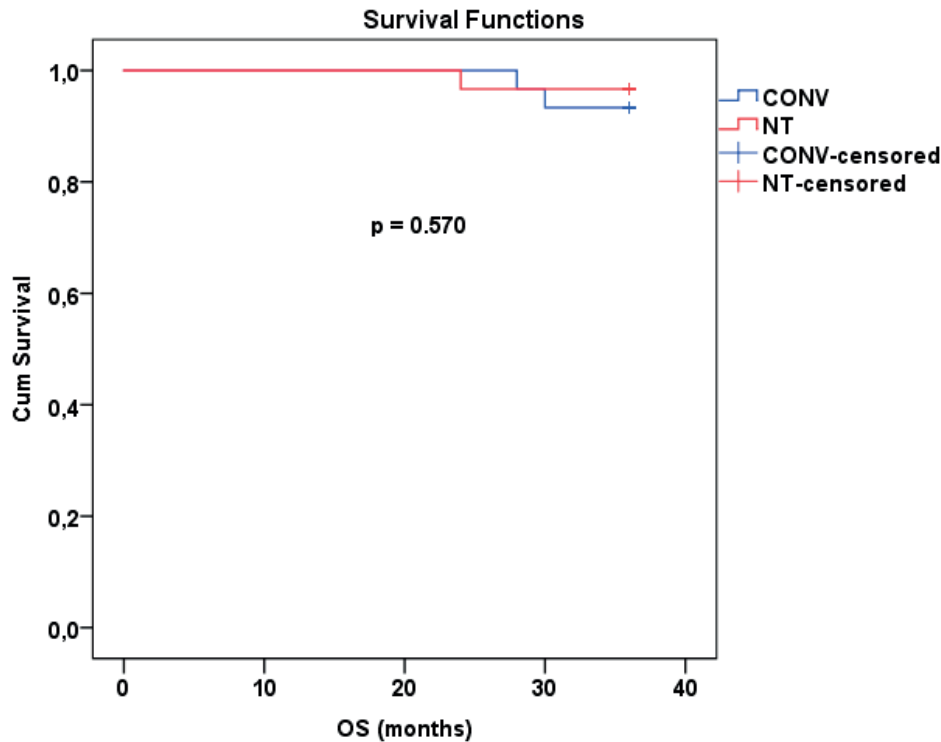
Complications	Group				<i>P</i>
	CONV		NT		
	(n = 30)		(n = 30)		
	n	%	n	%	
Wound infection (7D)	0	0.0%	1	3.3%	1.000a
Wound infection (3M)	0	0.0%	2	6.7%	0.492a
Wound infection (6M)	0	0.0%	0	0.0%	NA
Wound dehiscence (7D)	1	3.3%	3	10.0%	0.612a
Wound dehiscence (3M)	2	6.7%	3	10.0%	1.000a
Wound dehiscence (6M)	0	0.0%	0	0.0%	NA
Hematoma (7D)	18	60.0%	6	20.0%	0.003a
Hematoma (3M)	0	0.0%	0	0.0%	NA
Hematoma (6M)	0	0.0%	0	0.0%	NA
Neurodeficit (7D)	6	20.0%	6	20.0%	1.000a
Neurodeficit (3M)	3	10.0%	1	3.3%	0.612a
Neurodeficit (6M)	2	6.7%	1	3.3%	1.000a
Peripheral edema (7D)	16	53.3%	10	33.3%	0.192a
Peripheral edema (3M)	5	16.7%	3	10.0%	0.706a
Peripheral edema (6M)	4	13.3%	2	6.7%	0.671a

Table 2. Evaluation of CT coronary angiography 1 year after surgery.

	CONV		NT		<i>P</i> (Fisher's Exact Test)
	<i>n</i>	%	<i>n</i>	%	
Total	27		26		
Stenosis LITA-LAD	0	0%	0	0%	NA
Stenosis of vein graft	3	11%	0	0%	0.236
RCA	1	4%	0	0%	1.000
CX	1	4%	0	0%	1.000
RD	0	0%	0	0%	NA
OM	1	4%	0	0%	1.000
Stenosis up to 50% (treated conservatively)	2	7%	0	0%	0.491
Stenosis greater than 50% (treated with stent implantation)	1	4%	0	0%	1.000

Table 3. MACE – Major adverse cardiovascular events – after 1 year.

	CONV	NT	<i>P</i> (Fisher's Exact Test)
Nonfatal stroke	4 (13%)	1 (3%)	0.353
Nonfatal myocardial infarction	(10%)	0 (0%)	0.237
Cardiovascular death	0 (0%)	0 (0%)	NA

**Fig. 5.** The Kaplan-Meier curve.

Kaplan-Meier curves of overall survival in patients undergoing no-touch (NT) versus conventional (CONV) saphenous vein harvesting during coronary artery bypass surgery. Time zero was defined as the date of surgery. Tick marks indicate censored observations. No evidence of a statistically significant difference in overall survival was observed between groups (log-rank test, $P=0.570$). OS, Overall Survival; Cum Survival, Cumulative Survival.

practice and research primarily focus on complications of wound healing after sternotomy; however, healing complications at the site of GSV harvesting are significantly more common. These complications significantly prolong hospitalization, increase treatment costs, and negatively affect the patient's overall recovery¹². In our cohort, we observed only mild soft tissue healing complications, including superficial wound dehiscence at the vein harvesting site. These events were limited to partial skin separation without involvement of deeper tissue layers and had no impact on graft integrity. Their treatment was based on moist wound healing, while in more severe cases vacuum-assisted closure therapy would be indicated; however, such therapy was not required or used in any of the patients included in this study. In rare cases, complicated secondary healing may require cooperation with a plastic surgeon. In extreme cases, limb amputation may be necessary¹⁹. Such serious complications significantly reduce the patient's quality of life and can also lead to psychological stress.

Risk factors for wound healing disorders after GSV saphenous vein harvesting can be divided into preoperative and intraoperative factors. Preoperative factors include older age, diabetes mellitus, obesity (high BMI), anemia (hematocrit < 35%), heart failure, female gender, ischemic disease of the lower extremities, smoking, and chronic renal failure. Intraoperative factors primarily include the technique used for GSV harvesting and the introduction of intra-aortic balloon counterpulsation (IABP) into the limb from which the graft was harvested¹⁹.

In the postoperative period, the lower incidence of soft tissue healing complications in the NT group may, at least in part, have been influenced by the lower proportion of patients with diabetes (CONV 56.6% vs. NT 23.3%; $P=0.017$).

In addition to diabetes mellitus, graft length represents another potential confounding factor when interpreting wound-related outcomes. The significantly shorter venous grafts harvested in the NT group may have resulted

in fewer skin incisions and reduced surgical manipulation, particularly in the region around the knee, which is known to be more susceptible to impaired wound healing. Therefore, the observed differences in soft tissue healing complications are likely influenced by a combination of baseline patient characteristics and procedural factors rather than by the harvesting technique alone.

The role of female gender as an independent risk factor remains a matter of controversy. Two main hypotheses are being considered: a smaller caliber of peripheral arteries in women and hormonal influences associated with the postmenopausal period. In our cohort, the representation of women was similar in both groups (26.7% vs. 20%; $P=0.761$), and their proportion was not sufficient to influence the results. In obese patients and diabetics, the risk of healing disorders is generally higher, mainly due to microangiopathy, reduced tissue perfusion, and immune mechanism disorders. Wound healing disorders after GSV harvesting are therefore multifactorial¹⁹.

Serious complications can be prevented through careful preoperative examination, identification of risk factors, selection of the optimal harvesting technique, meticulous surgical technique, and early detection of even mild impaired wound healing²⁰. Patient risk stratification is therefore crucial for selecting the appropriate venous graft harvesting method.

In our cohort, lower intraoperative blood loss was recorded in patients in the NT group (CONV 40 ± 12.1 mL vs. NT 15 ± 7 mL; $P<0.0001$). The NT method was also associated with a shorter time required for graft harvesting (CONV 43 ± 9.1 min vs. NT 35 ± 7.5 min; $P=0.001$). As the harmonic scalpel was used in the same standardized fashion in both groups, the observed differences are more likely attributable to procedural factors, particularly the shorter length of the venous graft harvested in the NT group (CONV 36 cm vs. NT 27 cm; $P=0.293$), rather than to the harvesting instrument itself. The lower incidence of subcutaneous hematoma in the NT group (60% vs. 20%; $P=0.003$) may further reflect reduced tissue trauma and fewer side branches requiring hemostasis as a consequence of shorter graft length. Other intraoperative parameters were comparable between the two groups, and no statistically significant differences were observed. Minimally invasive techniques for GSV harvesting are currently considered an effective strategy for reducing the risk of early complications, especially in high-risk patients^{21,22}. Endoscopic harvesting is associated with a statistically significantly lower incidence of healing complications compared to the classic open method²². Based on these results, the endoscopic technique is often preferred in patients at increased risk of wound infectious complications.

However, in patients without significant risk factors, the NT harvesting technique may be a more suitable alternative. Although it is associated with a slightly higher incidence of healing disorders^{8,10}, it offers significantly better long-term patency than both the conventional and endoscopic techniques^{8,23}. The NT method has been included in the European guidelines for myocardial revascu-

larization (Class IIA, Level of Evidence B) as a safe and effective way to improve the patency of venous grafts²⁴.

This technique has been evaluated in two extensive multicenter studies. A study of Tian et al. demonstrated a lower incidence of venous graft occlusion and angina recurrence in patients treated with the NT technique, a comparable incidence of MACE, but a higher frequency of wound complications at the donor site¹⁰. Another comparable study of Ragnarsson et al. confirmed the similar safety profile of the two methods and described a slightly increased risk of soft tissue healing disorders⁹.

In our study, no evidence of a statistically significant difference in soft tissue healing disorders was demonstrated after GSV harvesting. CT coronary angiography 1 year after surgery showed no stenosis at the LITA-LAD anastomosis in either group. Venous bypass stenosis was more common in the CONV group (13% vs. 0%; $P=0.236$); however, no evidence of a statistically significant difference in venous graft patency was found between the groups. Given the limited sample size, the study was not powered to detect small or moderate differences, and definitive conclusions regarding equivalence cannot be drawn.

Importantly, the present study was not designed or powered to formally test equivalence between harvesting techniques. The absence of statistically significant differences should therefore be interpreted as indicating no evidence of a large effect in this selected cohort rather than confirming comparable outcomes.

Limitations

The present study has several limitations. First, its single-center observational design and relatively small sample size limit statistical power, and the analysis was underpowered to detect anything other than large differences in wound-related complications, major adverse cardiovascular events, or graft patency. Patient allocation was based on routine clinical practice without randomization or allocation concealment, which may have introduced selection bias despite the inclusion of consecutive patients.

Second, the study population represents a particularly low-risk cohort, as reflected by very low overall event rates and the absence of wound infections in the conventional harvesting group, which is lower than typically reported in the published literature. Consequently, even if clinically meaningful differences between harvesting techniques existed, the present study would be unlikely to detect them.

Third, baseline imbalances between groups, particularly the lower proportion of patients with diabetes mellitus in the NT group, as well as procedural factors such as shorter graft length, may have confounded the comparison of donor-site wound healing outcomes. Finally, the duration of follow-up was limited to one year for graft patency assessment and may not fully capture late vein graft failure or long-term clinical outcomes. Therefore, the findings should be interpreted as exploratory and hypothesis-generating rather than confirmatory.

CONCLUSION

The NT technique for saphenous vein harvesting was associated with perioperative advantages, including shorter harvesting time, reduced blood loss, and a lower incidence of early subcutaneous hematoma, without prolongation of operative or aortic cross-clamp time. In this small, low-risk cohort, no evidence of a statistically significant increase in wound complications, MACE, or impaired venous graft patency at one-year follow-up was observed. Given the limited sample size, these findings should be interpreted as exploratory and hypothesis-generating rather than confirmatory. Larger, adequately powered studies are required to define the clinical impact of the NT harvesting technique more definitively.

ABBREVIATIONS

NT, The no-touch; CABG, coronary artery bypass grafting; CONV, conventional saphenous vein harvesting; MACE, major adverse cardiovascular events; GSV, great saphenous vein; LITA, left internal thoracic artery; CT, computed tomography; BMI, body mass index; IABP, intra-aortic balloon counterpulsation; LAD, left artery descending; RCA, right coronary artery; CX, left circumflex artery; D, diagonal branch; OM, obtuse (left) marginal branch; LITA, left internal thoracic artery; CPB, cardiopulmonary bypass.

Acknowledgements: Acknowledgment to Elad Ben Aharon Farzalla (Sheba Medical Center, Israel) for assistance with English language editing of the manuscript. Supported by the Ministry of Health, Czech Republic – conceptual development of research organization (FNOL, 0098892). **Authors contributions:** All authors contributed in patient enrollment as well as the literature search and manuscript writing. They all read and approved the final manuscript. **Conflict of interest statement:** None declared.

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