ORIGINAL ARTICLE – OTHER

Editor's Choice – Infra-inguinal Endovascular Revascularisation and Bypass Surgery for Chronic Limb Threatening Ischaemia: a Retrospective European Multicentre Cohort Study with Propensity Score Matching

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WHAT THIS PAPER ADDS

This study demonstrates that in patients with chronic limb threatening ischaemia, amputation free survival and healing rate after first time revascularisation are significantly improved with bypass surgery compared with endovascular treatment.

Objective: The aim of this study was to compare the long term efficacy of lower limb bypass with that of endovascular treatment (EVT) in patients with chronic limb threatening ischaemia (CLTI).

Methods: This retrospective, multicentre study evaluated the outcomes of patients with CLTI who underwent first time infra-inguinal bypass or EVT. The primary outcome was to compare amputation free survival (AFS) rates between the two propensity score matched groups. The secondary outcome was to compare wound healing within the first six months. Major adverse events were compared according to the type of revascularisation.

Results: Overall, 793 patients fulfilled the eligibility criteria, from whom 236 propensity score matched pairs were analysed. The mean follow up was 52 months. The 236 bypass procedures included 190 autogenous bypass grafts (80.5%), 151 (64.0%) of which were infrapopliteal. Among the 236 EVT procedures, the target lesion was the femoropopliteal segment in 81 patients (34.3%), the femoropopliteal and infrapopliteal segments in 101 patients (42.8%), and the infrapopliteal segment in 54 patients (22.9%). AFS was significantly better in the bypass group at five years (60.5 $\pm$ 3.6%) compared with the EVT group (35.3 $\pm$ 3.6%) ($p < .001$). Major amputation occurred in 61 patients (25.8%) in the bypass group and 85 patients (36.0%) in the EVT group (HR 0.66, 95% CI 0.47 — 0.92; $p = .014$). The probability of healing was significantly better in the bypass group at six months compared with the EVT group ($p = .003$). The median length of stay was shorter for the EVT group (4 days) than for the bypass group (8 days) ($p = .001$). Urgent re-intervention and re-admission rates were high and did not differ significantly between the groups.

Conclusion: This study has shown that lower limb bypass surgery offered a significantly higher probability of AFS and wound healing compared with EVT in patients with CLTI.

Keywords: Angioplasty of the arteries of the lower limbs, Chronic limb threatening ischaemia, Lower limb bypass, Propensity score analysis, Survival without amputation

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INTRODUCTION

The rate of chronic limb threatening ischaemia (CLTI), the most advanced peripheral artery disease, is increasing, driven by rising rates of diabetes and an ageing population.[1,2] Revascularisation by either bypass surgery or endovascular treatment (EVT) is the first line treatment for CLTI. EVT has gained dominance as a less invasive procedure involving a shorter hospital stay.[3,4] Supporters of EVT propose that advances in EVT technology have allowed outcomes close to bypass surgery and that the extra morbidity of surgery outweighs its potential benefit.[5,6]

Until recently, evidence favouring either strategy in patients with CLTI was limited to one randomised study, the BASIL-1 trial published in 2005.[7,8] That study demonstrated that in patients who survived more than two years, bypass surgery was associated with a better outcome in terms of amputation free survival (AFS). Recent publication of the BEST-CLI trial[9] further supports surgery as the more durable approach, especially when a great saphenous vein conduit is available. But the recently published BASIL-2 trial [10] gives an opposite result, with a recommendation for an endovascular first revascularisation strategy.

The aim of this study was to help answer the question as to which technique offers the best long term outcome by making a comparative analysis of the two methods using data obtained from four centres in a cohort of CLTI patients matched by propensity score.

METHODS

A retrospective cohort study design was employed using hospital charts of patients with CLTI treated between January 2015 and December 2021 in four European vascular centres (University of Poitiers, University of Clermont-Ferrand, University of Toulouse [all in France], and University of Rome, La Sapienza, in Italy).

Supra-inguinal revascularisation was excluded from the analysis. Patients with an incomplete follow up without arteriogram or non-invasive testing available for review, patients who had undergone previous ipsilateral infra-inguinal revascularisation procedures, and patients who had emergency surgery were also excluded (Fig. 1). Patient demographic and comorbidity covariables obtained from the medical records were centralised for review.

Definitions

A CLTI diagnosis was defined as chronic ischaemic pain at rest with ankle pressure < 50 mmHg, toe pressure < 30 mmHg, or ischaemic foot ulcer or gangrene with the same haemodynamic criteria. The WIfI (Wound, Ischaemia, and foot Infection) classification[11] was used to provide adequate staging of the severity of ischaemia. The GLASS (Global Limb Anatomic Staging System) classification[1] was used to grade the anatomy of arterial lesions, with the primary target artery defined as the optimal pathway to restore inline flow to the foot.

Adaptation of WIfI and GLASS classifications

Before the start of the study, there was poor interobserver agreement between study participants regarding the four WIfI stages (weighted κ 0.49). By grouping WIfI stages 1—2 *vs.* WIfI stages 3—4, interobserver agreement improved significantly (weighted κ 0.81). The newly introduced GLASS classification was also associated with poor interobserver agreement (weighted κ 0.31), which improved after grouping the three GLASS stages into two categories, GLASS stages 1 and 2 *vs.* GLASS stage 3 (weighted κ 0.88).[12] Classification of patients using the simplified grades was performed by two authors (J.B.R. and A.H.). Disagreements were resolved by a multidisciplinary consensus of the physicians in charge of the patients. Accordingly, WIfI and GLASS stages were appropriately reclassified in 82 patients.

Patients and data collection

All patients were enrolled in a follow up programme that involved duplex ultrasound (DUS) surveillance, measurement of ankle brachial pressure, or toe brachial index as appropriate, and a wound clinic at one, two, three, four, and six months after the procedure and every six months thereafter. Patient wound care and monitoring was performed by vascular surgeons and nurses in outpatient wound clinics.

Bypass surgery

For bypass surgery, the ipsilateral or contralateral great saphenous vein and the arm veins were evaluated preoperatively using DUS to check that the diameter was $>$ 2.5 mm and that the vein was suitable for a bypass. For tibial pass, the healthier artery that crossed the ankle was the target. In the setting of both a limited vein for bypass and a diseased superficial femoral artery (SFA), the combination of SFA angioplasty above a distal origin graft was used to offer patients a short autogenous bypass graft to a distal target.

Endovascular interventions

The strategy for femoropopliteal lesions was to use an optimal sized balloon after crossing the lesion. For severe dissection, a bare nitinol stent, a drug eluting stent, or a covered stent was used. For infrapopliteal lesions, a drug coated balloon was used preferentially. No atherectomy device was employed. All EVT procedures were performed by vascular surgeons.

Choice of revascularisation technique

The choice of revascularisation technique was determined by the vascular surgeons of each centre after assessment of each case by a multidisciplinary team.

Antithrombotic treatment

In the bypass group, aspirin (75 mg or 160 mg daily) or clopidogrel (75 mg daily) was started one week prior to the index operation. In the EVT group, aspirin and clopidogrel

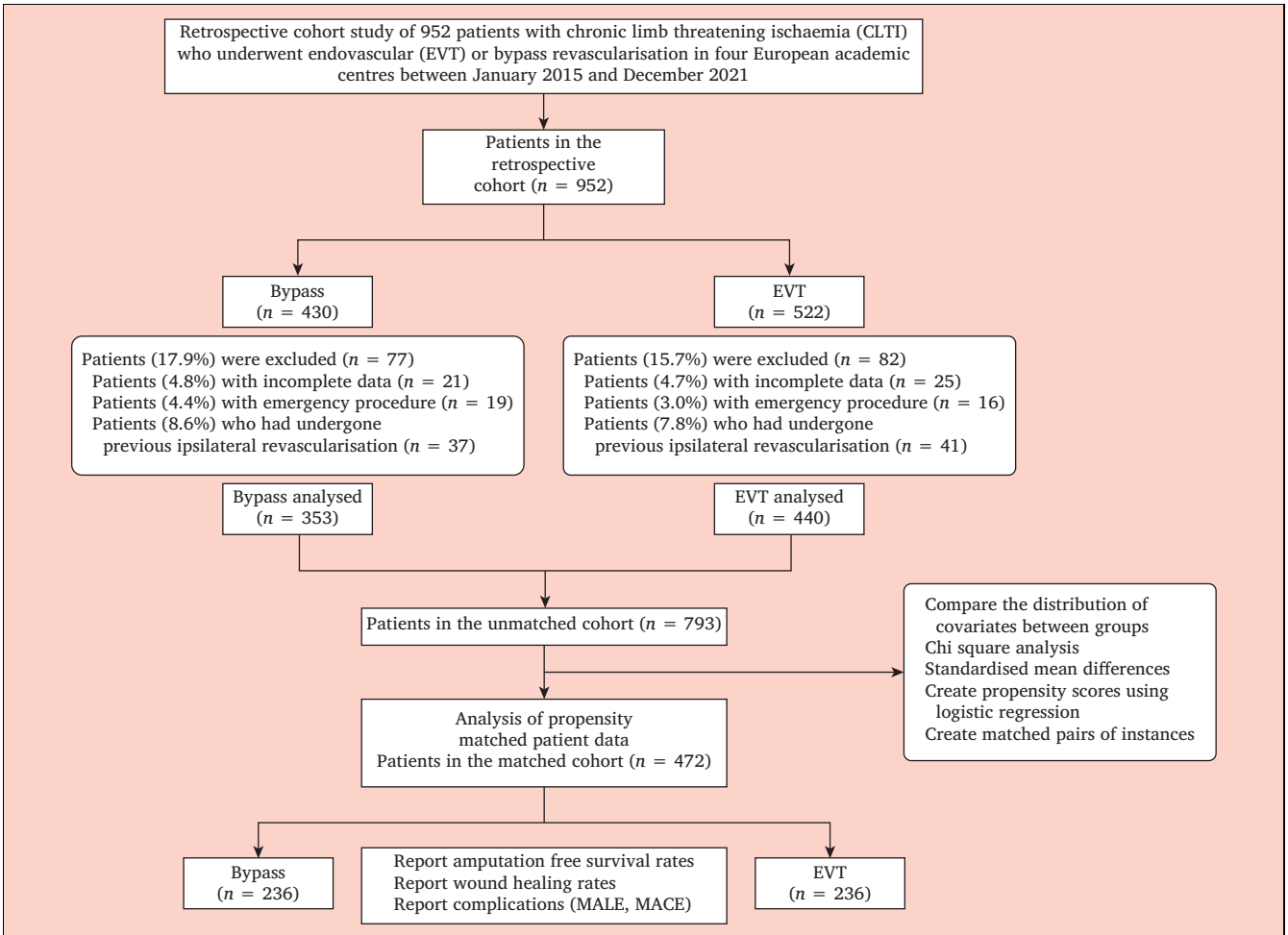

Figure 1. Flow chart showing the different phases of the study, selection of patients, and steps of the statistical analysis. In total, 159 patients (16.7%) were excluded, including 46 patients (4.8%) with incomplete data, 35 patients (3.7%) with emergency procedures, and 78 patients (8.2%) with a previous ipsilateral infra-inguinal revascularisation procedure. MALE = major adverse limb event; MACE = major adverse cardiovascular event.

were started one week prior to the index operation. The duration of dual antiplatelet therapy was dependent on the patient profile.

Major adverse events

Major adverse limb event (MALE) was defined as the occurrence of one or more of the following events in the target limb: major amputation, or an urgent revascularisation procedure. A major adverse cardiovascular event (MACE) included any of the following events: myocardial infarction, stroke, or death.

Outcomes

The primary outcome measure was the prevalence of major amputation or death (AFS) within each group of patients up to five years, and the ability of the WIfI and GLASS staging systems to predict this risk. Major amputation was defined as any amputation above the ankle. The secondary outcome was to determine the degree of complete or near complete healing, defined as healing of $>$ 90% of the wound surface within the first six months following the index procedure. A third outcome was to compare the incidence of MALE and MACE events as well as survival between the two groups.

Statistical analysis

Continuous variables are reported using the mean and standard deviation or median and interquartile range (IQR). Categorical variables are presented as counts and percentages and compared by Pearson's χ^2 test or Fisher's exact test. All statistical analyses were performed using R version 4.0.3 software (The R Foundation for Statistical Computing, Vienna, Austria) and MedCalc (Ostend, Belgium).

A χ^2 analysis of the pre-match main cohort of 793 patients revealed that between group distributions of the first seven covariables listed in Table 1 were significantly different. Table 1 also shows the standardised mean difference (SMD) scores for these same covariables to be $>$ 0.10. A propensity analysis was used to account for between group differences among these covariables (Supplementary File 1).

AFS was estimated in the matched cohorts at three years and five years using Kaplan–Meier life table methods.

Table 1. Baseline characteristics in the unmatched and propensity score-matched cohorts of bypass group and endovascular treatment (EVT) group

Covariates	Unmatched cohort (n = 793)				Matched cohort (n = 472)			
	Bypass (n = 353)	EVT (n = 440)	χ^2	SMD	Bypass (n =236)	EVT (n = 236)	χ^2	SMD
Age ≥ 80 years	103 (29)	164 (37)	.017	0.17	73 (31)	82 (35)	.38	0.08
GLASS stage 3 *	263 (75)	288 (65)	.006	0.19	171 (72)	175 (74)	.68	0.04
WIfI stages 3–4 †	202 (57)	141 (32)	<.001	0.52	109 (46)	108 (46)	.93	0.01
ASA Class 4 ‡	146 (41)	147 (33)	.021	0.16	89 (38)	80 (34)	.39	0.08
CHF §	190 (54)	264 (60)	.081	0.12	120 (51)	120 (51)	1.0	0.01
CKD ‖	124 (35)	102 (23)	<.001	0.26	79 (33)	81 (34)	.85	0.02
Diabetes mellitus	193 (55)	189 (43)	.001	0.23	117 (50)	122 (52)	.65	0.04
Dyslipidaemia	145 (41)	177 (40)	.81	0.01	85 (36)	90 (38)	.63	0.04
Hypertension	327 (93)	408 (93)	.96	0.04	225 (95)	224 (95)	.83	0.02
Tobacco use	215 (61)	286 (65)	.24	0.04	168 (71)	178 (75)	.30	0.09
Statin	257 (73)	322 (73)	.91	0.08	167 (71)	159 (67)	.43	0.07
Non-ambulatory	104 (29)	128 (29)	.91	0.08	78 (33)	76 (32)	.84	0.02
Male sex	264 (75)	334 (76)	.72	0.02	170 (72)	174 (74)	.68	0.04
COPD ¶	172 (49)	200 (45)	.36	0.06	112 (47)	113 (48)	.93	0.08
Previous stroke	20 (6)	21 (5)	.57	0.04	16 (7)	18 (8)	.72	0.03

Data are presented as n (%). Propensity score matching was computed from all the covariables with $p < .10$ in the unmatched cohort. Post-matched values of SMD (%) and p values for χ^2 covariates indicate minimal imbalance. SMD = standardised mean difference; GLASS = Global Limb Anatomic Staging System; WIfI = Wound, Ischaemia, and foot Infection; CHF = congestive heart failure; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease.

* GLASS stage 3 *vs.* stages 1–2.

† WIfI stages 3–4 *vs.* WIfI stages 1–2.

‡ ASA Class 4 *vs.* ASA Class 3.

§ CHF measured by left ventricular ejection fraction (LVEF) < 40% *vs.* ≥ 40%.

‖ CKD defined as estimated glomerular filtration rate (eGFR) < 30 mL/min/1.73 m^2.

¶ COPD defined as forced expiratory volume in 1 s (FEV_1) < 1 L.

Comparisons were calculated using multivariable Cox proportional hazards models with AFS as the explanatory variable. Patients lost to follow up during the study period were censored. A p value of < .05 was considered statistically significant, and all tests were two sided. Inter- and intra-observer variabilities were determined using weighted κ statistics.

This research was carried out in accordance with the Declaration of Helsinki and was approved by the ethics committee of each hospital without the need for informed consent, given the retrospective nature of the study design that followed the STROBE guidelines[12] for reporting of observational studies (Supplementary File 2).

RESULTS

A total of 159 patients (16.7%) were excluded from the initial cohort of 952 patients (Fig. 1). Data from the remaining 793 patient records were employed for the analysis.

Propensity score matching

Propensity score matching generated 236 matched pairs (472 patients). The post-match χ^2 test results given in Table 1 show that the pre-match known covariable bias between the two groups was no longer seen in the 236 matched pairs. The post-match absolute SMD scores in Table 1 offer additional support for covariable balance between the groups.[13]

The evidence of covariable balance resulting from the propensity analysis can be graphically displayed. Figure 2A provides a visual picture of the imbalance in propensity scores between the groups prior to matching. The diagram shows a histogram resting horizontally on its base for each group. The histograms are attached at their base by the vertical line labelled "0".

Figure 2B displays the histograms after matching. Each histogram signifies 236 instances. The distribution of propensity scores between the groups is now highly similar. Additional graphical evidence for post-match between group balance is given in Figure 3 which displays pre-and post-matched SMD values.

Bypass group

Table 2 shows the characteristics of the 236 bypass group patients resulting from the matching procedure. Briefly, 190 bypass grafts (80.5%) were autogenous, including 46 arm veins, and 46 were prosthetic. Also, 147 bypass grafts (62.3%) originated from below the common femoral artery. In this group, 45 patients (19.1%) with various degrees of SFA stenosis received a SFA percutaneous intervention followed by distal origin graft placement.

Endovascular treatment group

Table 3 shows the characteristics of the 236 patients in the EVT group. A total of 191 patients (80.9%) underwent balloon angioplasty, of whom 98 (41.5%) had a drug coated balloon.

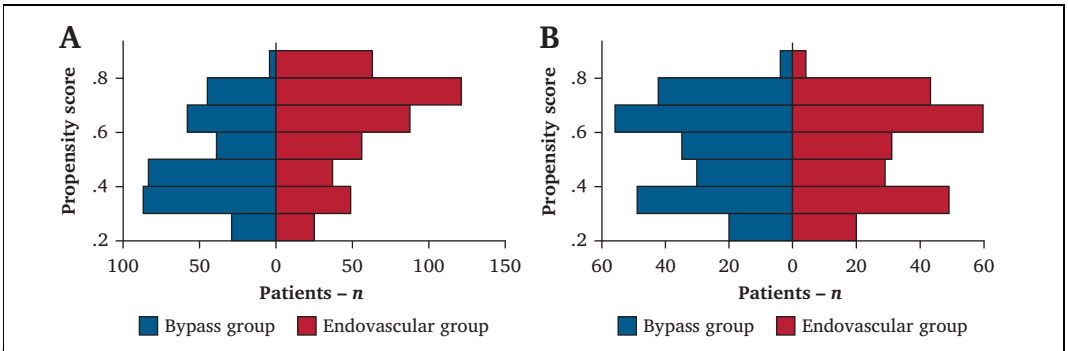

Figure 2. (A) Back to back histogram showing the distribution of propensity scores produced by logistic regression on 793 patients treated for peripheral artery disease (353 receiving bypass surgery and 440 endovascular treatment) with range between 0.2 and 0.875. The graph makes it clear that the two groups are not balanced. (B) Back to back histogram showing the distribution of propensity scores after adding computed propensity scores to the original patient data and applying the *matchit* function. The matched dataset contains 472 instances (236 matched pairs of patients). The graph makes obvious the covariable balance between the two groups of patients.

Distribution of patients in the four centres

The distribution of techniques (EVT or bypass) was not significantly different in the four centres (Supplementary File 3).

Technical success of procedures

The technical success of the index procedure was significantly better for the bypass group (228/236, 96.6%) compared with the EVT group (212/236, 89.8%) ($p = .005$). Early technical failures in the bypass group resulted in four redo bypass procedures and two EVT procedures. EVT group failures led to 15 redo EVT procedures and 9 bypass procedures.

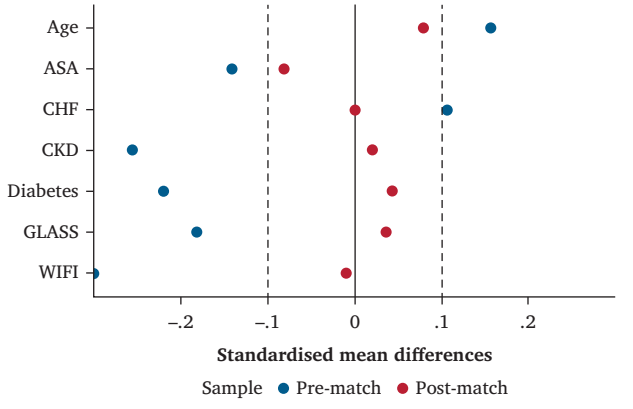

Figure 3. Covariable balance pre- and post-matching according to absolute standardised mean differences. Graph of standardised mean differences (bypass *vs.* endovascular treatment) before and after matching. The graph was obtained by applying R's *love.plot* function to the output of the *matchit* function. Pre-match dots signify between group covariable differences obtained from the original data prior to matching. Post-match dots denote between group differences after matching. All post-match standardised mean differences fall in the range of −0.10 to 0.10 thereby supporting between group covariable balance. Age > 80 years; ASA Class 4; CHF = congestive heart failure measured by left ventricular ejection fraction (LVEF) < 40%; CKD = chronic kidney disease defined as estimated glomerular filtration rate (eGFR) < 30 mL/min/1.73 m^2; GLASS (Global Limb Anatomic Staging System) stage 3; WIfI (Wound, Ischaemia, and foot Infection), WIfI stages 3–4.

Main outcomes

The bypass group was associated with a significantly higher rate of AFS (Fig. 4), with 72.1 ± 3.0% at three years and 60.5 ± 3.6% at five years compared with 62.0 ± 3.2% at three years and 35.3 ± 3.6% at five years in the EVT group ($p < .001$).

The probability of healing, according to Kaplan–Meier estimate, in patients with an ischaemic wound or a minor amputation performed during the index operation was 64.8 ± 5.0% at three months and 82.0 ± 7.6% at six months in the bypass group compared with 33.7 ± 6.2% at three months and 45.2 ± 6.9% at six months in the EVT group ($p = .003$) (Fig. 5).

The mean duration of follow up was 52 months [95% confidence interval (CI) 50 – 55 months]. The median duration of hospitalisation was four days (IQR 2, 6 days) in the EVT group and 8 days (IQR 3, 12 days) in the bypass group ($p = .001$).

Major adverse events

At 52 months, the rate of MALE was significantly lower in the bypass group (43.6% *vs.* 55.1%; $p = .011$) (Table 4). This was driven primarily by a significantly higher rate of amputation in the EVT group (36.0% *vs.* 25.8%; $p = .014$). MACE rates were not significantly different between the two groups (43.2% bypass *vs.* 43.6% EVT; $p = .463$). The overall survival probability at 52 months was 62.8 ± 2.7%, with a survival probability of 63.9 ± 4.0% in the bypass group and 61.5 ± 3.8% in the EVT group ($p = .52$). Urgent re-interventions did not differ significantly between the groups, with 52 (22.0%) urgent re-operations in the bypass group and 62 (26.3%) in the EVT group ($p = .28$). Similarly, urgent all cause re-admissions were also frequent, with 80

Table 2. Technical features of 236 infra-inguinal bypass operations in the propensity score matched cohort

Inflow	Operations	Outflow	Bypass graft (all) (n = 236)	Vein graft (n = 190) *	Prosthetic graft (n = 46)	Bypass with SFA intervention (n = 45) †
CFA	89 (37.7)	AK popliteal	12 (5.1)	2	10	0
		BK popliteal-TPT	30 (12.7)	14	16	0
		ATA-peroneal-PTA-DPA	47 (19.9)	42 (1 ‡)	5	0
SFA	68 (28.8)	AK popliteal	21 (8.9)	9	12	0
		BK popliteal-TPT	15 (6.4)	15 (3 ‡)	0	3
		ATA-peroneal-PTA-DPA	32 (13.6)	32 (5 ‡)	0	6
AK popliteal artery	28 (11.9)	BK popliteal-TPT	7 (3.0)	4	3	4
		ATA-peroneal-PTA-DPA	21 (8.9)	21 (9 ‡)	0	9
BK popliteal artery	51 (21.6)	ATA-peroneal-PTA-DPA	51 (21.6)	51 (28 ‡)	0	23

Data are presented as n (%). SFA = superficial femoral artery; CFA = common femoral artery; AK = above knee; BK = below knee; TPT = tibioperoneal trunk; ATA = anterior tibial artery; PTA = posterior tibial artery; DPA = dorsal pedis artery.
* Vein grafts originated from the ipsilateral great saphenous vein (n = 102), contralateral great saphenous vein (n = 42), and arm veins (n = 46).
† Hybrid procedures in patients with varying degrees of SFA stenosis with percutaneous intervention (angioplasty or stenting) to optimise inflow for distal origin bypass grafts and to optimise the use of autogenous bypass graft to a distal target.
‡ Arm veins.

(33.9%) re-admissions in the bypass group and 96 (40.7%) in the EVT group (p = .13).

Re-interventions

In the EVT group, a first re-intervention (elective or urgent) occurred in 104 limbs (44.1%), with a second or a third re-intervention in 41 limbs (17.4%). The bypass group showed comparable results, with a first re-intervention in 106 limbs (44.9%) and a second or third re-intervention in 28 limbs (11.9%) (Supplementary File 4).

Impact of WIfI and GLASS classifications

The impact of GLASS and WIfI classification was analysed using a Cox regression model. Patients classified as GLASS stage 3 had a significantly higher hazard ratio (HR) of death or major amputation compared with patients at GLASS 1—2 (HR 1.53, 95% CI 1.02 — 2.32; p = .039). Similarly, patients classified as WIfI 3—4 had a significantly higher HR of death or major amputation compared with patients with WIfI 1—2 (HR 1.52, 95% CI 1.17 — 1.99; p = .002).

DISCUSSION

This study has demonstrated that bypass surgery provided better outcomes compared with EVT with respect to AFS as well as ischaemic wound healing rates. These are two outcomes of primary importance for CLTI patients. The median four day hospital stay for EVT patients was significantly shorter than the eight day median stay for the bypass group (p = .001). Urgent re-interventions as well as urgent all cause re-admissions were frequent and did not differ significantly between the groups.

Most previous studies have focused on survival, limb salvage, or AFS, but these outcomes cannot determine whether, and after how many weeks, wound healing is achieved in patients with CLTI. In this study, AFS and wound healing together made it possible to assess the effectiveness of revascularisation.

Since publication of the BASIL-1 trial[7], EVT has evolved and has been viewed as a modern, less invasive procedure with a significantly shorter length of hospital stay best suited for CLTI patients at higher risk of surgery.[14,15] The recently published BEST-CLI trial provides substantial clarity

Table 3. Technical features of 236 infra-inguinal endovascular procedures in the propensity score matched cohort

Target lesion	Procedures	Devices used	Procedures (n = 236)
Femoropopliteal only	81 (34.3)	Bare metal stent	20 (8.5)
		Drug eluting stent	21 (8.9)
		Covered stent	4 (1.7)
		Balloon angioplasty	24 (10.2)
		Drug coated balloon	12 (5.1)
Femoropopliteal + infrapopliteal	101 (42.8)	Bare metal stent (FP) + balloon angioplasty (IP)	27 (11.4)
		Drug eluting stent (FP) + balloon angioplasty (IP)	24 (10.2)
		Covered stent (FP) + balloon angioplasty (IP)	7 (3.0)
		Balloon angioplasty (FP) + drug-coated balloon (IP)	21 (8.9)
		Drug coated balloon (FP) + drug-coated balloon (IP)	22 (9.3)
Infrapopliteal only	54 (22.9)	Balloon angioplasty	11 (4.7)
		Drug coated balloon	43 (18.2)

Data are presented as n (%). FP = femoropopliteal; IP = infrapopliteal. Among the techniques used in the endovascular treatment (EVT) group, a drug coated balloon was used in 143 procedures and a drug eluting stent in 45 procedures, for a total of 143/236 EVT procedures (60.6%).

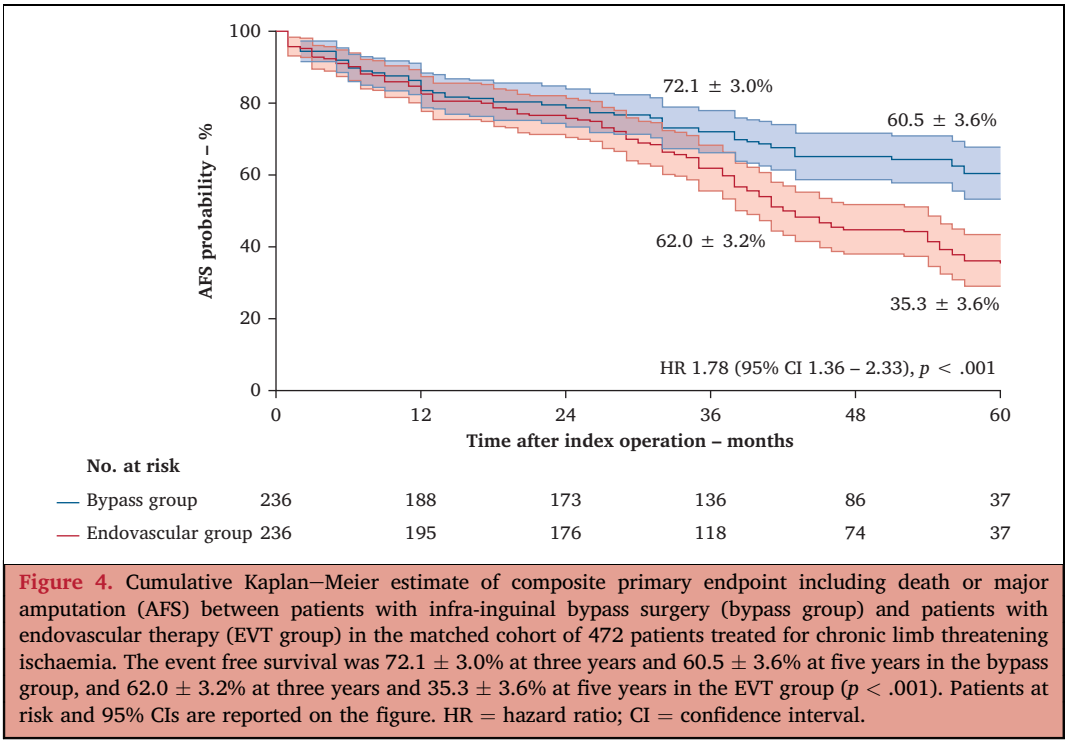

Figure 4. Cumulative Kaplan–Meier estimate of composite primary endpoint including death or major amputation (AFS) between patients with infra-inguinal bypass surgery (bypass group) and patients with endovascular therapy (EVT group) in the matched cohort of 472 patients treated for chronic limb threatening ischaemia. The event free survival was 72.1 ± 3.0% at three years and 60.5 ± 3.6% at five years in the bypass group, and 62.0 ± 3.2% at three years and 35.3 ± 3.6% at five years in the EVT group ($p < .001$). Patients at risk and 95% CIs are reported on the figure. HR = hazard ratio; CI = confidence interval.

about the midterm outcome (2.7 years median follow up), showing a lower incidence of a major adverse limb event or death in bypass patients compared with the EVT group. The present research supports these results.

Interestingly, the between group difference observed in the BEST-CLI trial was not significant in patients requiring alternative bypass conduits. This emphasises the current European Society for Vascular Surgery (ESVS) guidelines recommendation[2] to use a great saphenous vein for bypasses by systematically seeking it in both lower limbs. This was the practice with 80.5% of autogenous bypasses. Such a result was made possible by systematic pre-operative DUS assessment of saphenous veins and arm veins, together with the deliberate choice of a bypass inflow located downstream from the common femoral artery in 147 patients (62.3%). In 45 of these cases with SFA stenosis and

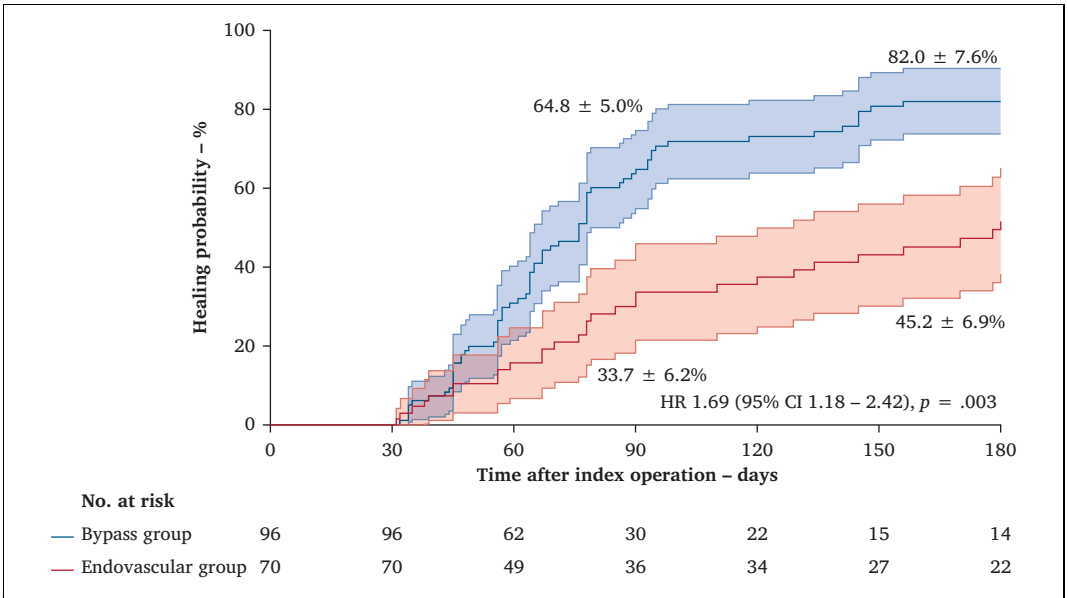

Figure 5. Cumulative Kaplan–Meier estimate of probability of healing in patients with an ischaemic wound or a minor amputation completed after propensity score matching. In the bypass group, 96 of 109 patients (WIfI 3–4) presented with tissue loss. In the EVT group, 70 of 108 patients (WIfI 3–4) presented with tissue loss. The probability of healing according to Kaplan–Meier estimate was 64.8 ± 5.0% at three months and 82.0 ± 7.6% at six months in the bypass group, and 33.7 ± 6.2% at three months and 45.2 ± 6.9% at six months in the EVT group ($p = .003$). Patients at risk and 95% CIs are reported on the figure. HR = hazard ratio; CI = confidence interval; EVT = endovascular therapy; WIfI = Wound, Ischaemia, and foot Infection.

Table 4. Outcomes at 52 months following bypass surgery and endovascular treatment (EVT) in the propensity score matched cohort

Outcome	Cumulative incidence for bypass surgery (n = 236)	Cumulative incidence for EVT (n = 236)	HR (95% CI)	p value
MALE and components				
MALE	103 (43.6)	130 (55.1)	0.63 (0.44–0.91)	.011
Major amputation	61 (25.8)	85 (36.0)	0.66 (0.47–0.92)	.014
Urgent bypass	16 (6.8)	12 (5.1)	1.35 (0.62–2.93)	.44
rgent EVT	24 (10.2)	30 (12.7)	0.77 (0.43–1.37)	.39
Thrombolysis	14 (5.9)	17 (7.2)	0.81 (0.39–1.68)	.58
Major bleeding	2 (0.8)	3 (1.3)	0.66 (0.10–4.00)	.66
All urgent re-interventions	52 (22.0)	62 (26.3)	0.79 (0.51–1.21)	.28
Less severe limb events				
Elective bypass	35 (14.8)	24 (10.2)	1.53 (0.88–2.67)	.13
Elective EVT	31 (13.1)	38 (16.1)	0.78 (0.47–1.31)	.36
Minor amputation	8 (3.4)	19 (8.1)	0.40 (0.17–0.93)	.034
Re-admission for less severe limb event	80 (33.9)	96 (40.7)	0.74 (0.51–1.08)	.13
MACE and components				
MACE	102 (43.2)	103 (43.6)	0.98 (0.68–1.41)	.46
Myocardial infarction	48 (20.3)	44 (18.6)	1.09 (0.69–1.70)	.70
Stroke	12 (5.1)	13 (5.5)	0.92 (0.41–2.06)	.85
Death	52 (22.0)	58 (24.6)	1.15 (0.75–1.77)	.59

Data are presented as n (%), unless stated otherwise. Cumulative incidence of events at a mean follow up of 52 months (95% CI 50 − 55 months). HR = hazard ratio; CI = confidence interval; MALE = major adverse limb event; MACE = major adverse cardiovascular event.

limited vein graft length, a combination of SFA angioplasty above a distal origin graft allowed the patient to be offered autogenous grafting to a distal target.

One similarity between BEST-CLI and the present study is apparent. Both studies included the use of up to date endovascular techniques such as drug coated balloons or drug eluting stents (62% in BEST-CLI, 60.6% in the present study). In this study, reimbursement issues resulted in the exclusion of atherectomy devices.

There are several differences between the two studies. The mean follow up of this study was 52 months (95% CI 50 − 55 months) compared with a 32 month mean follow up in BEST-CLI. Amputation rates were higher in this study, however the 10.9% (bypass) and 14.9% (EVT) amputation rates reported in BEST-CLI were limited to patients with a single segment great saphenous vein bypass and shorter follow up. In contrast to BEST-CLI, the recently published BASIL-2 trial found that vein bypass, as a first revascularisation strategy, was associated with an increased risk of major amputation or death.[10] This difference was mainly driven by fewer deaths in the EVT group with similar limb based outcomes between the two groups. However, in BEST-CLI and the present study, no significant difference in all cause mortality was observed between the groups.

Relevance of GLASS and WIfI classifications

Since GLASS classifications are based on an expert consensus among the authors of the global vascular guidelines[1], the result of the current study is useful as confirmation of the clinical value of risk analysis using GLASS. A recent meta-analysis by Shirasu *et al*[16] suggested that advanced GLASS stages favour bypass surgery over EVT. However, in this meta-analysis, based mostly on observational studies, the absence of propensity matching between variables was susceptible to confounding factors.

In this study, WIfI advanced grades (3—4) were also associated with a higher risk of death or major amputation (AFS). Under these conditions, an endovascular first approach may result in an increased risk of re-intervention and major amputation.[17—20]

Relevance of propensity score matching

Most retrospective cohorts observing the role of bypass *vs.* EVT in CLTI patients are unbalanced relative to the different risk factors including, but not limited to, WIfI and GLASS stages. Only two recent observational studies attempted to balance intergroup differences in baseline characteristics by propensity score matching.[21—23] The SPINACH study[21] compared surgical bypass and EVT in 548 CLTI patients. After propensity score matching, three year AFS was not significantly different between the two groups. However, Utsunomiya *et al*[23] re-analysed the SPINACH study data and found that despite more severe GLASS and WIfI stages in the bypass group, limb based patency at three months was significantly better in the bypass group (73.8%) than in the EVT group (46.2%).

Another retrospective study by Parvar *et al*[22] used 1:1 propensity score matching in the subgroup of patients with CLTI (n = 8 112) and found that EVT was associated with higher hazard rates for the composite endpoint of death or MALE.

The present study is in line with these two studies.[22,23] Before propensity score matching, patients with more severe chronic ischaemia (WIfI grades 3–4) including tissue loss and more complex arterial lesions (GLASS grade 3) received bypass surgery more often than EVT (Table 1). After matching, the bypass group was associated with a higher probability of AFS and a better healing rate of ischaemic wounds. The latter may be related to higher flow in bypass grafts anastomosed to a vessel that had uninterrupted inline flow to the foot.[24]

Study limitations

This study was retrospective and, despite propensity score matching, the possibility of unmeasured confounders cannot be excluded. However, the post-matched χ^2 and SMD values shown in Table 1 for all competing covariables, including those not directly part of the propensity analysis, support minimal residual disparity.

Another potential limitation concerns the retrospective assessment of WIfI and GLASS grades. At the start of this study, Mills *et al* had just published their seminal paper on WIfI stratification[11], and it was not until 2019, in the midst of study recruitment, that Conte *et al* described the GLASS classification.[1] Even while recognising the risk of misclassification, centralisation of all data enabled the reclassification of 82 patients with a misclassified WIfI or GLASS stage. Finally, disparities in state funding of French and Italian university hospitals did not allow conduct of a cost analysis of the EVT and bypass groups.

Conclusion

The results obtained in this study provide strong positive evidence that patients receiving bypass surgery to treat CLTI have a significantly higher probability of amputation-free survival and wound healing compared with patients treated with an endovascular procedure. The rate of urgent re-intervention and re-admission remains high for individuals receiving either procedure.

CONFLICTS OF INTEREST

None declared.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2023.06.031

REFERENCES

1 Conte MS, Bradbury AW, Kolh P, White JV, Dick F, Fitridge R, et al. Global vascular guidelines on the management of chronic limb-threatening ischemia. *Eur J Vasc Endovasc Surg* 2019;**58**(1S):S1–109.

2 Aboyans V, Ricco JB, Bartelink MEL, Bjorck M, Brodmann M, Cohnert T, et al. 2017 ESC guidelines on the diagnosis and treatment of peripheral arterial diseases, in collaboration with the European Society for Vascular Surgery (ESVS): document covering atherosclerotic disease of extracranial carotid and vertebral, mesenteric, renal, upper and lower extremity arteries. Endorsed by: the European Stroke Organization (ESO), The Task Force for the Diagnosis and Treatment of Peripheral Arterial Diseases of the European Society of Cardiology (ESC) and of the European Society for Vascular Surgery (ESVS). *Eur Heart J* 2018;**39**:763–816.

3 Tang L, Paravastu SCV, Thomas SD, Tan E, Farmer E, Varcoe RL. Cost analysis of initial treatment with endovascular revascularization, open surgery, or primary major amputation in patients with peripheral artery disease. *J Endovasc Ther* 2018;**25**:504–11.

4 Gerhard-Herman MD, Gornik HL, Barrett C, Barshes NR, Corriere MA, Drachman DE, et al. 2016 AHA/ACC guideline on the management of patients with lower extremity peripheral artery disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation* 2017;**135**:e726–79.

5 Mehaffey JH, Hawkins RB, Fashandi A, Cherry KJ, Kern JA, Kron IL, et al. Lower extremity bypass for critical limb ischemia decreases major adverse limb events with equivalent cardiac risk compared with endovascular intervention. *J Vasc Surg* 2017;**66**:1109–16.

6 Rossi FH, Giusti JCG, Cury MVM, Beraldo JPN, Brochado Neto FC, Kambara AM. Real life outcomes of infrapopliteal endovascular and surgical bypass intervention for chronic limb threatening ischaemia in GLASS stages II and III. *Eur J Vasc Endovasc Surg* 2022;**64**:41–8.

7 Adam DJ, Beard JD, Cleveland T, Bell J, Bradbury AW, Forbes JF, et al. Bypass versus Angioplasty in Severe Ischaemia of the Leg (BASIL): multicentre, randomised controlled trial. *Lancet* 2005;**366**:1925–34.

8 Bradbury AW, Adam DJ, Bell J, Forbes JF, Fowkes FG, Gillespie I, et al. Bypass versus Angioplasty in Severe Ischaemia of the Leg (BASIL) trial: a survival prediction model to facilitate clinical decision making. *J Vasc Surg* 2010;**51**(5 Suppl):52S–68S.

9 Farber A, Menard MT, Conte MS, Kaufman JA, Powell RJ, Choudhry NK, et al. Surgery or endovascular therapy for chronic limb-threatening ischemia. *N Engl J Med* 2022;**387**:2305–16.

10 Bradbury AW, Moakes CA, Popplewell M, Meecham L, Bate GR, Kelly L, et al. A vein bypass first versus a best endovascular treatment first revascularisation strategy for patients with chronic limb threatening ischaemia who required an infra-popliteal, with or without an additional more proximal infra-inguinal revascularisation procedure to restore limb perfusion (BASIL-2): an open-label, randomised, multicentre, phase 3 trial. *Lancet* 2023;**401**:1798–809.

11 Mills Sr JL, Conte MS, Armstrong DG, Pomposelli FB, Schanzer A, Sidawy AN, et al. The Society for Vascular Surgery lower extremity threatened limb classification system: risk stratification based on Wound, Ischemia, and foot Infection (WIfI). *J Vasc Surg* 2014;**59**:220–34.

12 von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;**61**:344–9.

13 Austin PC. Propensity-score matching in the cardiovascular surgery literature from 2004 to 2006: a systematic review and suggestions for improvement. *J Thorac Cardiovasc Surg* 2007;**134**:1128–35.

14 Hiramoto JS, Teraa M, de Borst GJ, Conte MS. Interventions for lower extremity peripheral artery disease. *Nat Rev Cardiol* 2018;**15**:332–50.

15 Li B, Rizkallah P, Eisenberg N, Forbes TL, Roche-Nagle G. Rates of intervention for claudication versus chronic limb-threatening ischemia in Canada and United States. *Ann Vasc Surg* 2022;**82**:131–43.

16 Shirasu T, Takagi H, Gregg A, Kuno T, Yasuhara J, Kent KC, et al. Predictability of the Global Limb Anatomic Staging System (GLASS) for technical and limb related outcomes: a systematic review and meta-analysis. *Eur J Vasc Endovasc Surg* 2022;**64**:32–40.

17 Hicks CW, Canner JK, Sherman RL, Black 3rd JH, Lum YW, Abularrage CJ. Evaluation of revascularization benefit quartiles

using the Wound, Ischemia, and foot Infection classification system for diabetic patients with chronic limb-threatening ischemia. *J Vasc Surg* 2021;**74**:1232–9.
18 Ramanan B, Ahmed A, Wu B, Causey MW, Gasper WJ, Vartanian SM, et al. Determinants of midterm functional outcomes, wound healing, and resources used in a hospital-based limb preservation program. *J Vasc Surg* 2017;**66**:1765–74.
19 Hossain S, Leblanc D, Farber A, Power AH, DeRose G, Duncan A, et al. Editor's Choice – Infrainguinal bypass following failed endovascular intervention compared with primary bypass: a systematic review and meta-analysis. *Eur J Vasc Endovasc Surg* 2019;**57**:382–91.
20 Tokuda T, Oba Y, Koshida R, Suzuki Y, Murata A, Ito T. Prediction of the technical success of endovascular therapy in patients with critical limb threatening ischaemia using the Global Limb Anatomical Staging System. *Eur J Vasc Endovasc Surg* 2020;**60**:696–702.
21 Iida O, Takahara M, Soga Y, Kodama A, Terashi H, Azuma N, et al. Three-year outcomes of surgical versus endovascular revascularization for critical limb ischemia: the SPINACH study (Surgical Reconstruction Versus Peripheral Intervention in Patients With Critical Limb Ischemia). *Circ Cardiovasc Interv* 2017;**10**:e005531.
22 Parvar SL, Ngo L, Dawson J, Nicholls SJ, Fitridge R, Psaltis PJ, et al. Long-term outcomes following endovascular and surgical revascularization for peripheral artery disease: a propensity score-matched analysis. *Eur Heart J* 2021;**43**:32–40.
23 Utsunomiya M, Takahara M, Iida O, Soga Y, Hata Y, Shiraki T, et al. Limb-based patency after surgical vs endovascular revascularization in patients with chronic limb-threatening ischemia. *J Endovasc Ther* 2020;**27**:584–94.
24 Morisaki K, Matsubara Y, Kurose S, Yoshino S, Furuyama T. Bypass surgery provides better outcomes compared with endovascular therapy in the composite endpoint comprising relief from rest pain, wound healing, limb salvage, and survival after infra-inguinal revascularisation in patients with chronic limb threatening ischaemia. *Eur J Vasc Endovasc Surg* 2022;**63**:588–93.

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COUP D'OEIL

Extensive Vertebral Erosion Due to a Large Thoracic Aortic Aneurysm

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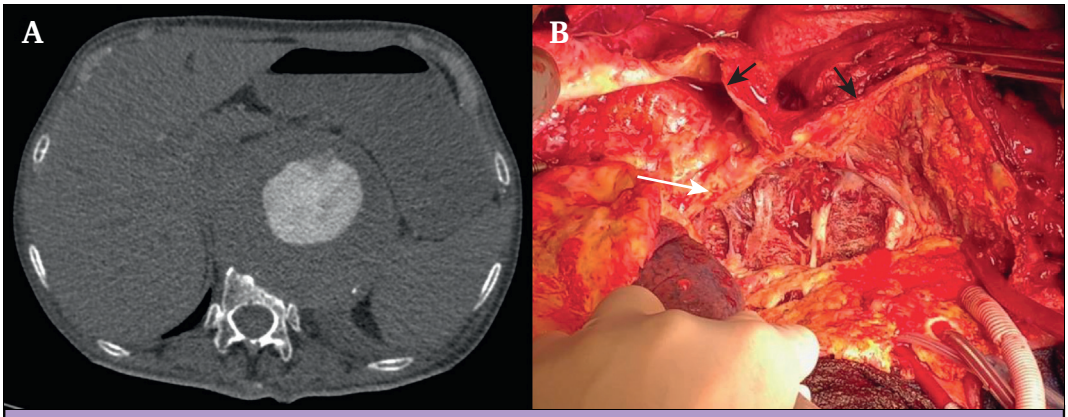

A 64 year old female was referred with a 10 cm diameter thoracic aortic aneurysm. The patient had been complaining of severe backpain for almost two years. Work up showed extensive vertebral erosion due to a large thoracic aortic aneurysm (A). An open thoraco-abdominal surgical repair was performed with partial cardiopulmonary bypass (femoral cannulation) and visceral cannulation. After opening the aneurysm (B, black arrow), an eroded aortic wall and vertebrae (B, white arrow) were noted but did not require orthopaedic stabilisation. Bone wax was placed on the eroded vertebrae, and they were covered with a part of the aneurysm wall to prevent erosion by the Dacron graft.

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