Routine use of completion imaging after infrainguinal bypass is not associated with higher bypass graft patency

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Background: **Significant variability exists in completion imaging (CIM) after infrainguinal lower extremity bypass (LEB). We evaluated the use of CIM and compared graft patency in patients treated by surgeons who performed routine CIM vs those who performed selective CIM.**

Methods: **We reviewed the Vascular Study Group of New England database (2003-2010) and assessed the use of CIM (angiography or duplex ultrasound) among patients undergoing LEB. The surgeon-specific CIM strategy was categorized as routine (≥80% of LEBs) vs selective (<80% of LEBs). Exclusion criteria included acute limb ischemia, bilateral procedures, and surgeon volume <10 cases per study period. Primary graft patency at discharge and at 1 year was analyzed on the basis of CIM use and surgeon-specific CIM strategy. Multivariable analyses were performed using Poisson regression.**

Results: **Among 2032 LEB procedures performed by 48 surgeons, CIM was used in 1368 cases (67.3%). CIM was performed in 72% of autogenous LEBs and 52% of prosthetic grafts. Dialysis (odds ratio [OR], 1.7; 95% confidence interval [CI], 1.1-2.6; $P = .01$), elective LEB (OR, 2.6; 95% CI, 1.4-4.8; $P = .002$), great saphenous vein conduit (OR, 2.0; 95% CI, 1.6-2.5; $P < .001$), and tibial or pedal target artery (OR, 1.8; 95% CI, 1.4-2.3; $P < .001$) were associated with CIM use. In multivariate models, CIM was not associated with improved primary graft patency at discharge (OR, 1.1; 95% CI, 0.7-1.7; $P = .64$) or at 1 year (OR, 0.9; 95% CI, 0.7-1.2; $P = .47$). Sixteen surgeons (33%) were routine users and 32 (67%) were selective users of CIM. Among patients of routine vs selective CIM users, primary graft patency at discharge and at 1 year was 96% vs 94% ($P = .21$) and 68% vs 72% ($P = .09$), respectively. In multivariate analysis, routine or selective CIM strategy was not associated with improved discharge (rate ratio, 0.8; 95% CI, 0.6-1.1; $P = .31$) or 1-year (rate ratio, 1.1; 95% CI, 0.9-1.2; $P = .56$) graft patency.**

Conclusions: **In our observational cohort, CIM does not improve short-term and 1-year bypass graft patency in infrainguinal LEB. The surgeon-specific strategy of selective CIM after LEB has outcomes comparable to those of routine CIM. (J Vasc Surg 2014;60:678-85.)**

Infrainguinal lower extremity bypass (LEB) is an important treatment strategy in patients with symptomatic peripheral arterial disease who are at reasonable surgical risk and have a suitable bypass conduit.[1,2] A significant portion of patients treated with LEB experience early bypass graft failure secondary to intraoperative technical problems.[3-5] This has led many surgeons to employ completion imaging (CIM) (angiography or duplex ultrasound) to intraoperatively evaluate technical adequacy of the LEB.[6-11] CIM enables the surgeon to identify and therefore to correct technical defects in a timely manner, which may lead to improvement in bypass graft patency.[7,8,12-14]

There is evidence that CIM is effective in detecting technical problems during LEB[4,5,10,11,13] and is therefore valuable in such cases. Although the rationale for selective CIM use is indisputable, the role for routine CIM use is less clear.[15] Furthermore, some authors contend that not all defects seen on completion angiography are clinically significant and therefore do not affect long-term bypass outcomes.[16,17] Others have suggested that continuous waveform Doppler is the best indicator for technical errors and that CIM should be used selectively when continuous waveform Doppler suggests a potential problem.[15] Finally, routine CIM has been shown to lead to unnecessary surgical re-exploration in clinically satisfactory grafts, therefore leading to increased operating time and resource use.[17]

The purpose of this study was to use a large, prospectively collected database to evaluate the effect of CIM on outcomes after LEB. We also studied LEB outcomes of surgeons on the basis of their strategy of routine vs selective use of CIM.

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METHODS

Patients. Our study cohort included patients who underwent infrainguinal LEB by participants of the Vascular Study Group of New England (VSGNE). This cooperative quality improvement initiative was developed in 2002 to prospectively study regional outcomes of patients undergoing vascular surgery. The details of this registry have been previously published[18] and are available online at http://www.vsgne.org. The Institutional Review Board at Boston University School of Medicine has approved the use of the de-identified data for this study.

There were 3554 LEB procedures performed for claudication and critical limb ischemia by 71 surgeons in academic and community hospitals within VSGNE between 2003 and 2010. In this cohort, the bypass inflow origin included the common femoral artery, profunda femoris artery, superficial femoral artery, and above- or below-knee popliteal artery. Target outflow arteries included the above- or below-knee popliteal artery, tibioperoneal trunk, and tibial or pedal vessels. Conduits used included in situ saphenous vein, reversed vein, nonreversed vein, arm vein, and prosthetic grafts. Cases were excluded from evaluation (n = 1522) because of acute ischemia (n = 270), missing indication (n = 128), bilateral (n = 131) and concomitant procedure (n = 860), death at discharge (n = 30), and missing bypass graft patency information (n = 17). The most common concomitant procedure excluded was common femoral endarterectomy (n = 663). We also excluded 86 LEBs by surgeons who performed fewer than 10 cases per study period within VSGNE (23 surgeons) and were therefore unable to be classified with respect to their CIM strategy. The final study cohort included 2032 LEBs performed by 48 surgeons.

Outcome and variable definitions. Demographics, pre-existing medical comorbidities, and index operation details were reviewed. More than 100 clinical and demographic variables were collected prospectively and entered into the VSGNE database for each procedure.[18] Definitions of medical comorbidities in VSGNE have been previously described elsewhere.[18] CIM was defined as intraoperative angiography or duplex ultrasound scan performed during LEB. The decision to use CIM, interpretation of CIM findings, and decision for re-exploration were left to the discretion of individual surgeons and were not evaluable in this study. Main outcomes measured included primary bypass graft patency at discharge and at 1 year.

Statistical analysis. Our study consisted of two main analyses. First, the outcomes of LEB patients were compared on the basis of whether CIM was performed. This analysis was performed for the entire study cohort (n = 2032) as well as for patients treated with only autogenous bypass grafts (n = 1525). In the second analysis, surgeons were categorized into two groups on the basis of the percentage of LEB cases in which the surgeon elected to perform CIM. Patients with both autologous and prosthetic LEBs were included in this analysis. Those surgeons who performed CIM in ≥80% of LEBs were categorized as routine users of CIM, whereas those who performed CIM in <80% of LEBs were characterized as selective CIM users (Fig 1). Routine users were then compared with selective users on the basis of aggregated surgeon outcomes measures. Additional analyses were done after dividing the surgeons into tertiles based on the percentages of CIM performed. Outcomes of patients who had LEB performed by surgeons in the upper tertile were compared with those of patients who had LEB performed by surgeons in the lower tertile.

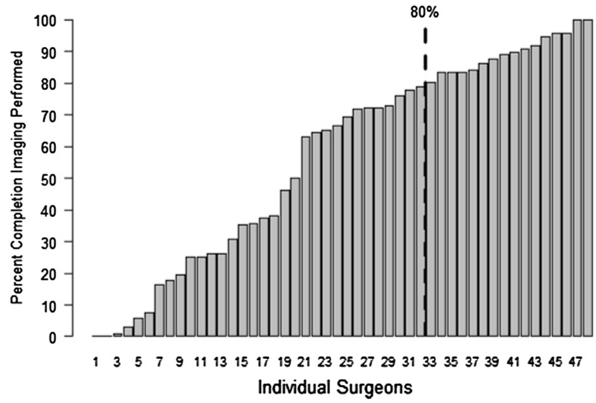

Fig 1. Use of completion imaging (CIM) after lower extremity bypass (LEB) among surgeons within the Vascular Study Group of New England (VSGNE).

Baseline demographic characteristics were compared by χ^2 test for categorical variables and Student *t*-test for continuous variables. Kaplan-Meier curves were constructed for the 1-year primary bypass graft patency. Multivariable logistic regression was used to evaluate factors associated with performance of CIM during LEB and factors associated with discharge and 1-year graft patency. These associations were expressed as adjusted odds ratios (AORs) with corresponding 95% confidence intervals (CIs). Multivariable Cox proportional hazards models were used to evaluate the effect of CIM on primary graft patency loss, reintervention, and major amputation. These associations were expressed as adjusted hazard ratios (AHRs) with corresponding 95% CI. Gamma regression model was used to evaluate the effect of CIM on hospital length of stay, and the associations were expressed as adjusted mean ratios with corresponding 95% CI. In all patient-level multivariable analyses, we initially included the following factors on the basis of the group difference at .2 α level as well as factors that were determined to be relevant clinically: patient age, race, smoking, hypertension, diabetes, end-stage renal disease (ESRD), indication for surgery (claudication vs critical limb ischemia), urgency, graft origin, graft recipient, and type of conduit. Backward elimination procedure with exit α level set at .2 was then used to construct parsimonious models.

For our second outcome analysis, multivariable Poisson regression models were used to compare aggregated counts of graft patency failure based on the surgeon's CIM

Table I. Demographic, patient, and operative characteristics of patients who did and did not undergo completion imaging (*CIM*) during lower extremity bypass (LEB)

Characteristic	*Overall (N = 2032)*	*CIM (n = 1368)*	*No CIM (n = 664)*	P *value*
Demographic				
Age, years	68.2 ± 11.9	68.5 ± 12	67.5 ± 11.8	.08
Male gender	1386 (68.2)	936 (68.4)	450 (67.8)	.80
White race	1999 (99.1)	1347 (99.3)	652 (98.6)	.13
Smoking				
Never	378 (18.6)	264 (19.3)	114 (17.2)	.02
Prior	890 (43.9)	619 (45.3)	271 (40.9)	
Current	761 (37.5)	483 (35.4)	278 (41.9)	
Medical comorbidity				
Hypertension	1748 (86)	1186 (86.7)	562 (84.6)	.22
Diabetes mellitus	1064 (52.4)	742 (54.2)	322 (48.5)	.02
Coronary artery disease	768 (37.8)	527 (38.5)	241 (36.4)	.38
Congestive heart failure	331 (16.3)	214 (15.6)	117 (17.6)	.28
Chronic pulmonary disease	525 (25.9)	349 (25.5)	176 (26.5)	.63
ESRD	157 (7.7)	121 (8.8)	36 (5.4)	.01
Aspirin	1436 (70.7)	961 (70.2)	475 (71.5)	.57
Clopidogrel	171 (8.4)	114 (8.3)	57 (8.6)	.87
Statin	1251 (61.6)	831 (60.8)	420 (63.3)	.28
Previous bypass	657 (32.3)	445 (32.5)	212 (31.9)	.80
Creatinine, mg/dL	1.5 ± 1.5	1.5 ± 1.6	1.5 ± 1.3	.28
Procedure detail				
Indication				
Claudication	544 (26.8)	340 (24.9)	204 (30.7)	.001
Rest pain	515 (25.3)	336 (24.6)	179 (27)	
Tissue loss	973 (47.9)	692 (50.6)	281 (42.3)	
Urgency				
Elective	1673 (82.3)	1150 (84.1)	523 (78.8)	.002
Urgent	345 (17)	213 (15.6)	132 (19.9)	
Emergent	14 (0.7)	5 (0.4)	9 (1.4)	
Anesthesia				
Spinal	330 (16.2)	231 (16.9)	99 (14.9)	.49
Epidural	138 (6.8)	90 (6.6)	48 (7.2)	
General	1563 (77)	1047 (76.5)	516 (77.8)	
Graft origin				
CFA, profunda, or SFA	1767 (88.8)	1209 (89.6)	558 (87.2)	.11
Above- and below-knee PA	222 (11.2)	140 (10.4)	82 (12.8)	
Graft recipient				
Above- and below-knee PA	1132 (55.8)	688 (50.3)	444 (67.1)	<.001
Tibioperoneal trunk, tibial or pedal artery	898 (44.2)	680 (49.7)	218 (32.9)	
Conduit type				
GSV	1364 (67.1)	979 (71.6)	385 (58)	<.001
Single segment	1329 (65.4)	950 (69.4)	379 (57.2)	
Multiple segments	34 (1.7)	29 (2.1)	5 (0.8)	
Arm vein	161 (7.9)	125 (9.1)	36 (5.4)	
Prosthetic	507 (25)	264 (19.3)	243 (36.6)	<.001

CFA, Common femoral artery; *ESRD,* end-stage renal disease; *GSV,* great saphenous vein; *PA,* popliteal artery; *SD,* standard deviation; *SFA,* superficial femoral artery.
Continuous data are presented as mean ± standard deviation and categorical data as number (%).

strategy (routine CIM vs selective CIM user and upper tertile vs lower tertile group) after adjustment for smoking, indication for surgery, graft origin, graft recipient, and type of conduit. These associations were expressed as rate ratios (RR) with corresponding 95% CI.

Analysis was performed with commercially available software (SAS 9.2; SAS Institute Inc, Cary, NC), and $P < .05$ was defined as statistically significant.

RESULTS

Use of CIM during LEB. Completion study was performed in 67% of patients (1368 LEBs). Seventy-two percent of autogenous grafts (1104 LEBs) and 52% of prosthetic grafts (264 LEBs) had CIM performed during surgery. The majority of CIM used was arteriography (89%), whereas duplex ultrasound was performed in 11% of cases. Demographic, clinical, and operative characteristics were compared between patients with LEB performed with and without CIM (Table I). Patients with diabetes, ESRD, and operation performed for critical limb ischemia were more likely to have CIM performed during their LEB. CIM was performed more often during elective surgery, when the outflow vessel was a tibioperoneal trunk or tibial or pedal artery, and when the great saphenous vein (GSV)

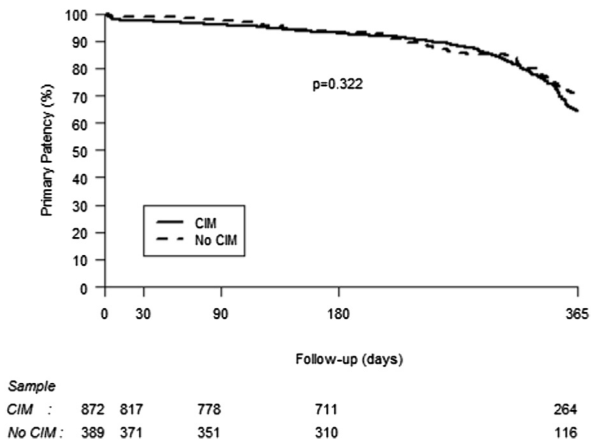

Fig 2. Kaplan-Meier curves of primary bypass graft patency among patients treated with lower extremity bypass (LEB) performed with or without completion imaging (*CIM*).

or an arm vein was used for the conduit. In bivariate analysis, primary bypass graft patency at discharge and at 1 year was similar in LEB procedures performed with or without CIM (Fig 2). Primary bypass graft patency at discharge and at 1 year was similar in LEB procedures performed with completion angiography and duplex ultrasound (data not shown).

In multivariable analysis, no significant differences were found in discharge (AOR, 1.1; 95% CI, 0.7-1.7; $P = .64$) and 1-year (AOR, 0.9; 95% CI, 0.7-1.2; $P = .47$) primary bypass graft patency on the basis of whether CIM was performed during LEB (Table II). Hospital lengths of stay were similar between both groups (adjusted mean ratio, 1.1; 95% CI, 1.0-1.1; $P = .07$). One-year mortality (AHR, 1.0; 95% CI, 0.7-1.4; $P = .91$), major amputation (AHR, 1.5; 95% CI, 0.9-2.4; $P = .14$), and reintervention (AHR, 1.0; 95% CI, 0.7-1.5; $P = .92$) were similar for LEBs performed with and without CIM.

Factors associated with use of CIM in the multivariable regression model included ESRD (AOR, 1.7; 95% CI, 1.1-2.6; $P = .01$), elective surgery (AOR, 2.6; 95% CI, 1.4-4.8; $P = .002$), popliteal artery origin (AOR, 0.5; 95% CI, 0.3-0.7; $P < .001$), tibioperoneal trunk or tibial or pedal artery bypass target (AOR, 1.8; 95% CI, 1.4-2.3; $P < .001$), and use of GSV as conduit (AOR, 2.0; 95% CI, 1.6-2.5; $P < .001$).

Use of CIM in autogenous LEB. Additional analysis was performed in LEB with autogenous graft (n = 1525 LEBs). There was no significant difference for primary bypass graft patency at discharge (94.5% vs 94.5%; $P = .962$) and 1 year (66.2% vs 68.5%; $P = .494$) for LEBs performed with and without CIM (Supplementary Table I, online only). Multivariable analysis revealed no significant difference in discharge patency (AOR, 1.1; 95% CI, 0.7-1.8; $P = .67$) and 1-year patency (AOR, 1.1; 95% CI, 0.8-1.5; $P = .62$) based on whether CIM was performed. Factors associated with CIM in autologous LEBs were elective surgery (AOR, 3.0; 95% CI, 1.5-5.9; $P = .002$), use of popliteal artery as origin (AOR, 0.5; 95% CI, 0.4-0.7; $P < .001$), and tibioperoneal trunk or tibial or pedal artery bypass target (AOR, 1.6; 95% CI, 1.3-2.1; $P < .001$).

Surgeon CIM strategy. Sixteen surgeons who performed 36.7% (1076) of the LEBs performed CIM in ≥80% of LEB procedures and were classified as routine CIM users, whereas 32 surgeons who performed 63.4% (1860) of the operations were classified as selective CIM users. Overall, 20 surgeons (41.7%) performed CIM in less than 60% of their LEBs (Fig 1). Twenty-six surgeons (54%) performed both angiography and duplex ultrasound during their LEBs. Among these surgeons, 14 (54%) used angiography more frequently than duplex ultrasound, nine (35%) used duplex ultrasound more frequently, and three (11%) used them equally frequently. The surgeon's case load during the study period, indication for surgery, bypass graft origin, and graft recipient were similar between LEBs performed by routine and selective CIM users (Table III). Routine CIM users performed a higher number of LEBs with the GSV as a conduit compared with selective CIM users. In bivariate analysis, there was no difference in primary bypass graft patency at discharge (routine, 95%, vs selective, 96%; $P = .21$) and 1 year (71.8% vs 68.2%; $P = .09$) in LEBs performed by these two groups of surgeons.

In multivariable analysis, the surgeon's strategy of performing routine vs selective CIM was not associated with primary graft patency at discharge (RR, 0.8; 95% CI, 0.6-1.1; $P = .31$) and at 1-year follow-up (RR, 1.1; 95% CI, 0.9-1.2; $P = .56$) (Table III). Among selective CIM users, factors associated with performance of CIM during LEB included ESRD, elective LEB, tibial or pedal outflow artery, and arm vein and GSV conduit (Table IV and Supplementary Table II, online only).

We performed additional analyses evaluating the outcomes of surgeons in the upper tertile and lower tertile based on percentages of CIM performed in their LEBs: primary bypass graft patency at discharge (upper tertile, 95.8%, vs lower tertile, 95.6%; $P = .86$) and 1 year (66.6% vs 70.1%; $P = .43$). In multivariable analysis, discharge graft patency (RR, 1.0; 95% CI, 0.5-1.8; $P = .95$) and graft patency at 1 year (RR, 1.2; 95% CI, 0.8-1.6; $P = .39$) were similar in LEBs performed by these two groups of surgeons.

DISCUSSION

Our study demonstrates significant variability in the CIM strategy used by surgeons performing LEB in New England. In 67% of LEB procedures, CIM was performed, and in the majority of cases, intraoperative angiography was the imaging modality of choice. CIM was performed in 70% of autogenous grafts and in more than half of prosthetic grafts. One third of the 48 surgeons included in this study performed CIM after LEB on a routine basis. CIM after LEB and the surgeon's strategy of routine CIM use were not associated with improvement in bypass graft patency at discharge or at 1 year.

Early bypass graft failure can be caused by technical error, poor conduit quality, insufficient arterial inflow, inadequate outflow target artery, and blood hypercoagulability.[5,19] It is associated with significantly decreased graft patency and

Table II. Multivariable analysis of the association between completion imaging (*CIM*) and primary bypass graft patency during lower extremity bypass (LEB)

	Adjusted estimate[a]	*95% Lower confidence limit*	*95% Upper confidence limit*	P *value*
Discharge patency				
CIM	1.11	0.72	1.70	.64
Age	1.01	0.99	1.03	.17
Hypertension	1.59	0.95	2.66	.08
Indication for surgery: claudication vs critical limb ischemia	1.54	0.89	2.66	.12
Graft recipient: popliteal vs tibial or pedal artery	2.86	1.79	4.53	<.001
Conduit type				
GSV vs prosthetic	1.43	0.86	2.38	.17
Arm vein vs prosthetic	0.83	0.41	1.69	.61
Autologous vs prosthetic	1.09	0.64	1.88	.75
One-year patency				
CIM	0.90	.68	1.20	.47
Age	1.01	1.0	1.02	.06
Indication for surgery: claudication vs critical limb ischemia	1.52	1.11	2.07	.01
Graft recipient: popliteal vs tibial or pedal artery	2.12	1.59	2.81	<.001
Conduit type				
GSV vs prosthetic	1.21	0.88	1.66	.24
Arm vein vs prosthetic	0.78	0.48	1.31	.36
Autologous vs prosthetic	0.98	0.68	1.40	.90
Patency loss hazard				
CIM	0.97	0.74	1.28	.83
Hypertension	0.72	0.52	1.01	.06
Graft recipient: popliteal vs tibial or pedal artery	0.48	0.36	0.64	<.001
Conduit type				
GSV vs prosthetic	0.69	0.51	0.94	.02
Arm vein vs prosthetic	0.97	0.62	1.52	.89
Autologous vs prosthetic	0.82	0.58	1.15	.24

AOR, Adjusted odds ratio; *GSV,* great saphenous vein; *HR,* hazard ratio.
[a]AOR for initial patency and 1-year patency and adjusted HR for patency loss.

increased risk of major complications, including reoperation, major amputation, and death.[20-22] Avoidance of early graft failure has led some surgeons to perform CIM, including arteriography and duplex ultrasound, to ensure technical adequacy of LEB.[5-8,10,11,16,19] Multiple studies have demonstrated excellent results in infrainguinal LEB performed with either routine completion angiography[7,16] or duplex ultrasound.[10,11,13,23]

Some studies have questioned the role of routine CIM.[15,17] In their prospective trial evaluating 54 infrainguinal LEBs, Blankensteijn et al[15] demonstrated that continuous waveform Doppler is the best method to detect intraoperative technical problems. The authors stated that routine intraoperative angiography was not necessary when Doppler insonation and palpation of the graft indicated a technically adequate bypass graft.[15] In addition, not all abnormalities noted on a completion angiogram are clinically significant and, as such, may not affect long-term outcomes of the bypass graft.[16,17] Others have also demonstrated that CIM added little additional information to standard evaluation techniques, especially when preoperative angiography was performed. Furthermore, CIM has been demonstrated to be associated with increased costs and resource use.[17]

In this study, CIM was performed in two thirds of autogenous grafts and in more than half of prosthetic grafts. Other studies have similarly evaluated CIM in LEB with prosthetic grafts.[7,15,24,25] To minimize potential bias, we performed analysis for the entire study cohort as well as for autogenous LEBs after exclusion of prosthetic conduits. The results were similar in that CIM did not improve bypass patency at discharge and 1 year for autogenous or prosthetic bypass grafts. The factors that prompted surgeons to perform CIM during LEB with use of an autogenous conduit were also similar and included elective surgery, popliteal artery as the origin, and tibioperoneal trunk or tibial or pedal artery as the bypass target.

In this study, we classified surgeons who performed CIM in ≥80% of LEBs as routine users and those who performed CIM in <80% as selective users. The outcomes of patients who had their LEBs performed by these two groups of surgeons were compared. Routine use of CIM did not improve bypass graft patency at discharge or at 1 year. The distribution of surgeons based on percentage of CIM performed in their bypasses was not bimodal in nature (Fig 1). Around 40% of surgeons performed CIM in less than 60% of their LEBs, and 37% of surgeons performed CIM in more than 80% of LEBs. The cutoff of

Table III. Surgeon's caseload and characteristics of lower extremity bypass (*LEB*) based on completion imaging (*CIM*)

Surgeon characteristic	*Selective CIM (n = 32), No. (%)*	*Routine CIM (n = 16), No. (%)*	P *value*
Total caseload			
10-20	8 (25)	5 (31.3)	.45
21-50	12 (37.5)	4 (25)	
51-100	9 (28.1)	3 (18.8)	
>100	3 (9.4)	4 (25)	
	LEB performed by selective CIM user (n = 1860), No. (%)	*LEB performed by routine CIM user (n = 1076), No. (%)*	P *value*
Characteristic			
Smoking			
Never	319 (17.2)	160 (14.9)	.02
Prior	802 (43.2)	521 (48.5)	
Current	735 (39.6)	394 (36.7)	
ESRD	125 (6.7)	112 (10.4)	<.001
Urgency			<.001
Elective	1447 (77.8)	948 (88.1)	
Urgent or emergent	413 (22.2)	128 (11.9)	
Indication			
Claudication	508 (27.3)	285 (26.5)	.25
Rest pain	490 (26.3)	260 (24.2)	
Tissue loss	862 (46.3)	531 (49.3)	
Graft origin			
CFA, profunda, or SFA	1667 (91.3)	952 (91.2)	.92
Above- or below-knee PA	159 (8.7)	92 (8.8)	
Graft recipient			
Above- or below-knee PA	1143 (61.5)	618 (57.5)	.03
Tibioperoneal trunk, tibial or pedal artery	715 (38.5)	457 (42.5)	
Conduit type			
GSV	1178 (63.3)	734 (68.2)	<.001
Arm vein	125 (6.7)	96 (8.9)	
Prosthetic	557 (29.9)	246 (22.9)	

CFA, Common femoral artery; *ESRD,* end-stage renal disease; *GSV,* great saphenous vein; *PA,* popliteal artery; *SFA,* superficial femoral artery.

Table IV. Multivariable analysis of factors associated with performance of completion imaging (CIM) by surgeon's strategy of selective CIM

	AOR	*95% Lower confidence limit*	*95% Upper confidence limit*	P *value*
ESRD	3.09	1.23	7.77	.02
Elective vs urgent or emergent	1.37	1.02	1.84	.03
Graft recipient: popliteal vs tibial or pedal artery	0.59	0.45	0.77	<.001
Graft vein type: arm vein vs none	2.12	1.23	3.67	.01
Graft vein type: GSV vs none	1.52	1.14	2.04	.01

AOR, Adjusted odds ratio; *ESRD*, end-stage renal disease; *GSV*, great saphenous vein.

80% was therefore made arbitrarily, and the decision to choose 80% as the cutoff value was made after performing a careful threshold analysis. Cutoff threshold analyses were performed with different potential cutoff points, including 90% vs 10%, upper vs lower tertile, and first quartile vs fourth quartile. In each of these analyses, the results obtained were similar, demonstrating no difference in outcomes between patients operated on by surgeons using routine vs selective CIM. In addition, after controlling for potential confounders, including indication, type of bypass, and conduit used, the surgeon's strategy of performing CIM routinely or selectively had no effect on bypass graft patency at discharge or at 1 year.

CIM has an important role in LEB, and to better understand its use, we evaluated the factors that prompt selective users to perform CIM. These included ESRD, distal bypass with tibial or pedal artery as the outflow target, and autologous conduit with GSV or arm vein. Of note,

selective users also performed CIM in up to one third of their LEBs with prosthetic grafts. LEBs performed by surgeons who used selective CIM had similar bypass graft patency at discharge and 1 year compared with routine CIM users. Selective CIM users were also more likely to perform CIM in elective settings. Our data suggest that the surgeon's strategy of performing CIM selectively is effective and can be associated with decreased operating time and resources.

There are important limitations to this study. This is an observational study of a prospectively collected regional database rather than a randomized controlled trial. The surgeons in the study were classified into routine or selective CIM users on the basis of the percentage of CIM performed in their LEBs. The cutoff of 80% in this study was arbitrarily made and might not reflect the true practice strategy of individual surgeons, but threshold analyses revealed that the results do not change when different cutoff values were tested. We were not able to determine the relationship between CIM and an individual surgeon's experience. Our study is limited by the variables collected within VSGNE, and therefore there may be potentially unaccounted cofounders in our analyses. We were not able to determine the frequency of abnormal CIM findings, the numbers of grafts that were revised on the basis of CIM findings, or the exact indication for performance of CIM in selective users because of the inherent limitation of the data set. The majority of CIM performed in this study was angiography, and no surgeon performed angioscopy. We were therefore unable to evaluate the efficacy of angioscopy as CIM in LEB.

Despite these limitations, the utility of the VSGNE database has been validated in other studies for patients undergoing vascular procedures.[26-29] Using this prospectively collected database, we were able to study large numbers of LEBs to evaluate the association of CIM with primary bypass graft patency. We were also able to appraise surgeons' preference of performing CIM routinely or selectively and to demonstrate that the surgeon's strategy of performing routine CIM is not associated with improvement in bypass graft patency.

CONCLUSIONS

Our study suggests that CIM does not improve short-term and 1-year bypass graft patency in autogenous or prosthetic infrainguinal LEBs. The surgeons' strategies of routine and selective CIM, especially in patients with ESRD, LEB with autogenous conduit, popliteal artery inflow, and distal target, are as effective for infrainguinal LEB.

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AUTHOR CONTRIBUTIONS

Conception and design: TT, JK, NH, AS, JC, AF
Analysis and interpretation: TT, DR, JK, GD, NH, AS, JC, AF
Data collection: TT, DR, GD
Writing the article: TT
Critical revision of the article: TT, DR, JK, GD, NH, AS, JC, AF
Final approval of the article: TT, AF
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Overall responsibility: AF

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Supplementary Table I (online only). Demographic, patient, and operative characteristics and bypass graft patency of autogenous lower extremity bypass (LEB)

Characteristic	*Overall (N = 1525)*	*CIM (n = 1104)*	*No CIM (n = 421)*	P *value*
Demographic				
Age, years	67.9 ± 12.1	68.1 ± 12.1	67.5 ± 11.9	.38
Male gender	1066 (69.9)	770 (69.7)	296 (70.3)	.85
White race	1499 (99)	1087 (99.3)	412 (98.3)	.14
Smoking				
Never	303 (19.9)	220 (19.9)	83 (19.7)	.76
Prior	667 (43.8)	488 (44.2)	179 (42.5)	
Current	554 (36.4)	395 (35.8)	159 (37.8)	
Medical comorbidity				
Hypertension	1305 (85.6)	948 (85.9)	357 (84.8)	.63
Diabetes mellitus	806 (52.9)	592 (53.6)	214 (50.8)	.33
Coronary heart disease	550 (36.1)	403 (36.5)	147 (35)	.59
Congestive heart failure	245 (16.1)	173 (15.7)	72 (17.1)	.53
Chronic pulmonary disease	361 (23.7)	262 (23.8)	99 (23.5)	.95
ESRD	122 (8)	97 (8.8)	25 (6)	.17
Creatinine, mg/dL	1.5 ± 1.6	1.5 ± 1.6	1.5 ± 1.4	.72
Aspirin	1067 (70)	775 (70.2)	292 (69.4)	.76
Clopidogrel	128 (8.4)	89 (8.1)	39 (9.3)	.47
Statin	916 (60.1)	651 (59)	265 (62.9)	.16
Previous bypass	444 (29.1)	330 (29.9)	114 (27.1)	.29
Creatinine, mg/dL	1.5 ± 1.6	1.5 ± 1.6	1.5 ± 1.4	.72
Procedure detail				
Indication				
Claudication	369 (24.2)	250 (22.6)	119 (28.3)	.06
Rest pain	381 (25)	276 (25)	105 (24.9)	
Tissue loss	775 (50.8)	578 (52.4)	197 (46.8)	
Urgency				
Elective	1248 (81.8)	928 (84.1)	320 (76)	<.001
Urgent	267 (17.5)	172 (15.6)	95 (22.6)	
Emergent	10 (0.7)	4 (0.4)	6 (1.4)	
Anesthesia				
Spinal	237 (15.6)	189 (17.1)	48 (11.4)	.02
Epidural	107 (7)	77 (7)	30 (7.1)	
General	1180 (77.4)	838 (75.9)	342 (81.4)	
Graft origin				
CFA, profunda, or SFA	1301 (86.1)	960 (87.8)	341 (81.8)	.004
Above- and below-knee PA	210 (13.9)	134 (12.2)	76 (18.2)	
Graft recipient				
Above- and below-knee PA	721 (47.3)	492 (44.6)	229 (54.5)	.001
Tibioperoneal trunk, tibial or pedal artery	803 (52.7)	612 (55.4)	191 (45.5)	
Graft vein type				
GSV (single)	1329 (87.2)	950 (86.1)	379 (90.2)	.06
GSV (multiple)	34 (2.2)	29 (2.6)	5 (1.2)	
Arm vein	161 (10.6)	125 (11.3)	36 (8.6)	
Outcome				
Discharge primary patency	1441 (94.5)	1043 (94.5)	398 (94.5)	.99
1-year primary patency	698 (66.7)	520 (66.2)	178 (68.5)	.54

CFA, Common femoral artery; *CIM,* completion imaging; *ESRD,* end-stage renal disease; *GSV,* great saphenous vein; *PA,* popliteal artery; *SD,* standard deviation; *SFA,* superficial femoral artery.

Continuous data are presented as mean ± standard deviation and categorical data as number (%).

Supplementary Table II (online only). Demographic, patient, and operative characteristics of lower extremity bypass (LEB) performed by selective completion imaging (*CIM*) surgeons

Characteristic	*Overall (N = 1240)*	*CIM (n = 667)*	*No CIM (n = 573)*	P *value*
Demographic				
Age, years, median and range	69 (25-96)	70 (25-95)	68 (26-96)	.13
Male gender	833 (67.2)	449 (67.3)	384 (67)	.95
White race	1221 (99.3)	658 (99.8)	563 (98.6)	.02
Smoking				
Never	240 (19.4)	137 (20.6)	103 (18)	.05
Prior	517 (41.8)	291 (43.7)	226 (39.5)	
Current	481 (38.9)	238 (35.7)	243 (42.5)	
Medical comorbidity				
Hypertension	1063 (85.7)	576 (86.4)	487 (85)	.52
Diabetes	655 (52.8)	368 (55.2)	287 (50.1)	.08
Coronary artery disease	473 (38.2)	262 (39.3)	211 (37)	.41
Congestive heart failure	212 (17.1)	109 (16.3)	103 (18)	.45
Chronic pulmonary disease	325 (26.2)	179 (26.8)	146 (25.5)	.61
ESRD	82 (6.6)	54 (8.1)	28 (4.9)	.07
Aspirin	860 (69.4)	452 (67.8)	408 (71.2)	.20
Clopidogrel	108 (8.7)	52 (7.8)	56 (9.8)	.23
Statin	765 (61.8)	405 (60.8)	360 (62.9)	.45
Previous bypass	387 (31.2)	211 (31.6)	176 (30.7)	.76
Creatinine, mg/dL	1.5 ± 1.4	1.5 ± 1.5	1.4 ± 1.3	.757
Procedure detail				
Indication				
Claudication	333 (26.9)	165 (24.7)	168 (29.3)	.104
Rest pain	327 (26.4)	173 (25.9)	154 (26.9)	
Tissue loss	580 (46.8)	329 (49.3)	251 (43.8)	
Urgency				
Elective	971 (78.3)	534 (80.1)	437 (76.3)	.110
Urgent	256 (20.6)	129 (19.3)	127 (22.2)	
Emergent	13 (1)	4 (0.6)	9 (1.6)	
Anesthesia				
Spinal	194 (15.7)	114 (17.1)	80 (14)	.025
Epidural	68 (5.5)	27 (4)	41 (7.2)	
General	977 (78.9)	526 (78.9)	451 (78.8)	
Graft origin				
CFA, profunda, or SFA	1080 (88.5)	589 (89)	491 (87.8)	.59
Above- and below-knee PA	141 (11.5)	73 (11)	68 (12.2)	
Graft recipient				
Above- and below-knee PA	709 (57.2)	335 (50.2)	374 (65.4)	<.001
Tibioperoneal trunk, tibial or pedal artery	530 (42.8)	332 (49.8)	198 (34.6)	
Graft vein type				<.001
GSV (single segment)	797 (64.3)	451 (67.6)	346 (60.5)	
GSV (multiple segments)	19 (1.5)	14 (2.1)	5 (0.9)	
Arm vein	90 (7.3)	60 (9)	30 (5.2)	
Prosthetic	333 (26.9)	142 (21.3)	191 (33.4)	

CFA, Common femoral artery; *ESRD,* end-stage renal disease; *GSV,* great saphenous vein; *PA,* popliteal artery; *SD,* standard deviation; *SFA,* superficial femoral artery.

Continuous data are presented as mean ± standard deviation and categorical data as number (%).