Does the experience of the endoscopic vein harvester matter to the quality of the vein conduit: A critical thematic literature review.

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Key words: Coronary Artery Bypass Graft surgery, Open vein harvesting;

Endoscopic vein harvesting, learning curve, conduit injury, graft patency.

Abstract.

Coronary Artery Bypass Graft (CABG) surgery remains the golden standard surgical option for multiple vessel disease. Harvesting the Long Saphenous Vein (LSV) using Endoscopic Vein Harvesting (EVH) requires advanced surgical skills dexterity, but the lack of a national standardised training programme allows for variance in the learning curve and the quality of the vein during the learning cycle is unknown. A search of bibliographic databases: CINHAL Plus; Embase; Pubmed and the Cochrane register for randomised controlled trials identified 11 articles eligible for review. The themes emerging were learning curve associated injuries to the LSV, intimal wall remodelling of the LSV and incidence of graft patency rates. Harvesting practitioners with less than 100 cases of experience inflict more conduit injuries leading to endothelial remodelling and narrowed vein grafts at the 6-month point resulting in lumen loss. Practitioners with more than 100 cases demonstrated reduced learning curve related injuries on the conduit. Adopting a formalised structured training programme such as the Manchester Endoscopic Learning Tool has shown to reduce endothelial injury to the LSV minimising early vein graft failure during the learning cycle.

Key Words: Coronary Artery Bypass Graft surgery; Open vein harvesting; Endoscopic vein harvesting, learning curve, conduit injury, graft patency.

Introduction:

Treatment strategies for Coronary Artery Disease (CAD) have been developed to include Coronary Artery Bypass Grafting (CABG) surgery that has evolved to become the most common adult cardiac surgery within the United Kingdom (UK), accounting for 13,000 procedures annually (Agarwal et al 2021, National Institute for Cardiac Outcomes Research (NICOR) 2021). Similarly, the choice of conduit has historically been in favour for total arterial revascularisation, however outcomes from the Radial Artery Patency and Clinical Outcomes (RAPCO) trial have demonstrated comparable outcomes when using the Long Saphenous Vein (LSV) which remains the most frequently used conduit (Buxton et al 2020). The traditional method of Open Vein Harvesting (OVH) is associated with complications that arise from the invasiveness of OVH pertaining to leg wound complications (2 to 40%) and postoperative pain that leads to increased length of stay and the associated costs from increased leg wound infection (Kiaii 2002, Krishnamoorthy et al 2012, Chernyavskiy et al 2015, Zenati et al 2019, Krishnamoorthy et al 2021).

The International Society for Minimally Invasive Surgery (ISMICS) recommend Endoscopic Vein Harvesting (EVH) based on Class 1, level B evidence, as the preferred harvesting technique (Ferdinand et al 2017). Uptake of EVH within the United States of America (USA) has been reported to be in the region of 80% for patients undergoing CABG (Ouzounian et al 2010). However, secondary analysis of the Prevent IV trial and the ROOBY trial reported increased vein graft failure and higher mortality rate within the EVH group, negatively impacting on the use of EVH within the UK (Lopes et al 2009, Zenati et al 2011, Soni et al 2019). Currently, the inferior clinical outcomes such as Major Adverse Cardiac Outcomes (MACE), vein graft patency and all-cause mortality remain a closely debated subject (Lopes et al 2009, Zenati et al 2011, Krishnamoorthy et al 2017, Krishnamoorthy et al 2021, Zenati et al 2019, Zenati et al 2021).

The Randomised Trial of Endoscopic or Open Vein Graft Harvesting for Coronary Artery Bypass (REGROUP) Trial (2019) explicitly used experienced harvesters for the study by predefining the inclusion criteria of experience: over 100 EVH cases; under five percent conversion rate from EVH to OVH; an established EVH programme with over two years' experience and similar levels of experience with OVH (Zenati et al 2019 and 2021). The measurement of harvesters' experience could be deemed difficult to objectify and standardise within research methods (Solli et al 2018). However, it has become common practice for regularly published authors within EVH studies to predefine experience by declaring: number of cases undertaken; conversion rates to OVH; number of cases performed by OVH or Standard Bridging Technique (SBT) and the cumulative length of experience of the harvesting practitioner (Krishnamoorthy et al 2012, Krishnamoorthy et al 2015, Krishnamoorthy et al 2017, Krishnamoorthy et al 2017b, Zenati et al 2019, Krishnamoorthy et al 2021, Zenati et al 2021).

Krishnamoorthy et al (2016) discussed the learning curve related problems such as: trauma to the conduit vein leading to early graft failure; lack of competency-based curriculum; lack of a standardised structured training programme and patient selection during the training period. High risk patients with diabetes, peripheral vascular disease, obese female patients with >30 BMI, and those with advanced chronic venous disease, should be omitted from the training period to improve patient outcomes (Krishnamoorthy et al 2016). This is consistent with the results collected by Ibrahim et al (2016) during simulation training for OVH where participants reported the benefits of practising complex steps in simulation prior to clinical practice. Krishnamoorthy et al (2016) report the advanced psychomotor skills required during EVH in comparison to OVH that could suggest the learning curve for EVH differs from other harvesting techniques. Therefore, the purpose of this comprehensive thematic review is to ascertain associated complications with EVH during the learning curve training period.

Methods:

It was the intention of the authors to undertake a systematic review and meta-analysis of the included studies at the onset. However, due to heterogeneity within the studies this was not possible. The emergence of the following themes: Learning curve related injuries to the LSV; Intimal wall remodelling of the LSV and Incidence of vein graft patency rates directed the review to follow a thematic review methodology.

Ethical approval: Ethical approval was obtained from the School of Research Ethics Panel (SREP) in line with local university protocol, research ethics application number: ETH2122-1723.

Search strategy and selection criteria:

The findings of the literature search were reproduced using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) to standardise how studies were identified for inclusion within the thematic review (Figure 1) (Boland et al 2017).

A search strategy from January 2002 to July 2024 of electronic bibliographic databases were searched: CINHAL Plus; Embase; Pubmed and the Cochrane register for controlled trials. Search terms were formulated using key words: (Endoscopic Vein Harvesting, EVH, Open Vein Harvesting, OVH, Long Saphenous Vein, LSV) AND (Coronary Artery Bypass Graft surgery, CABG, cardiac surgery, heart surgery). The inclusion criteria were as follows: original articles in English and accepted in a peer-reviewed journal, studies that had included participants who had undergone coronary artery bypass graft surgery, comparative studies investigating different harvesting techniques, and studies which have reported the target endpoints.

Data extraction and quality assessment:

Articles were screened by title and abstract by two independent reviewers, with relevant articles screened with full text review. Data abstraction was confirmed by two researchers with no discrepancies in the screening process. Consensus was reached following discussion regarding two articles surrounding the definition of all-cause mortality without the definition of cardiac mortality and the lack of definition of histological analysis.

Basic participant characteristics, study setting, study population, indication for intervention, harvest type, bypass details, anastomosis sites and clinical outcomes such as vein graft injuries or repairs, adventitial injury or bruising and vein graft occlusion rates were extracted. The quality of each trial was assessed using the Critical Appraisal Skills Programme (CASP) (Table 1).

The aim of this review was to investigate the learning curve period related conduit injuries, which was defined as vein repairs, graft damages, endothelial remodelling, and graft failure rates.

Statistical analysis:

Due to heterogeneity within the studies meta-analysis was not achievable, therefore, results from statistical analysis in the original reports were tabulated pertaining to learning curve associated injuries to the LSV, intimal wall remodelling of the LSV and graft patency rates. This review included mean values with ± standard deviation and percentages from the retrieved articles. Statistical significance was considered $p<0.05$.

Results:

A total of 141 records were found on the database search. After excluding duplicates, 123 publications were screened, full text review done on 36 articles, and 11 studies included in the review which fit with the inclusion criteria (Figure 1). Interestingly, only five articles mentioned learning curve associated vein injuries. The learning curve associated vein injuries were defined as adventitial damage, vein repairs, dissection related branch avulsion, and bruising of the vein walls. Eight studies provided relevant graft patency and intimal wall remodelling data, with three reporting on graft patency, three studies on graft occlusion and one study discussing about the repeat revascularisation in the presence of vein graft occlusion. Graft patency was defined as any blood flow through the length of the graft regardless of the presence of stenosis on day five postoperatively (Kiani et al 2012, Desai et al 2011) and at six months with good runoff and stenosis or partial occlusion of the graft less than 50% (Yun et al 2005). Furthermore, Kiani et al (2012) reported on vein lumen diameter at day five and at six months to assess vein graft patency demonstrating a higher incidence of lumen loss in the presence of four or more injuries to the vein graft during the harvesting process. Krishnamoorthy et al (2021) did not specifically analyse vein graft patency as a study primary outcome, but in the secondary outcomes reported on repeat revascularisation for vein graft occlusion in 0.1% of the EVH cohort in comparison to 0.2% in the OVH cohort. The basic characteristics of each trial included in this review are summarised in table 1. Overall, the 11 studies enrolled a total of 28,647 patients. The 11 studies included were: three retrospective; four prospective; three RCTs and one pilot RCT. The sample size ranged from 40 to 27,024 in all reviewed studies with one study involving 50 patients undergoing standard bridging harvesting technique (Table 1) (Krishnamoorthy et al 2012).

The articles selected were critically appraised using CASP tool and included 12 articles but only 11 have been reviewed. One article was excluded for the following reasons: the study was not statistically powered to analyse the long-term effects; the sample size was small (126) with only a 50% patient follow up; the author acknowledged that the results may only be hypothesis generating (Andreasen et al 2015).

Thematic literature review:

The thematic review compares two techniques of harvesting the LSV by OVH and EVH for CABG surgery on the relationship of the harvesting practitioner and the learning curve associated injuries to the LSV. This review will focus on the clinical outcomes of the conduit injury, intimal wall remodelling and vein graft patency.

Learning Curve associated injuries to the LSV (Table 2):

Learning curve for EVH has been explored by several authors and recommended a minimum case experience between 5 to 30 cases, (National Institute for Health and Care Excellence (NICE) 2014, Krishnamoorthy et al 2016 and Erden et al 2021). Coppoolse et al (1999) first described the learning curve for EVH should be 100 cases of EVH and would produce better outcomes. This was acknowledged by Erden and Gultekin (2021), but they concluded that the learning curve could be lowered to 20 cases. However, the study was underpowered and did not utilise the appropriate quantitative methods to draw such significant conclusions. The significance of the harvesting practitioners experience and transparency within reviews can be demonstrated when reviewing research conducted by Krishnamoorthy and Zenati with the routine publication of experience in articles published from 2012 onwards. Zenati et al (2019 and 2021) used a four-tiered system to define experience as a minimum of two years surgical experience in cardiac surgery; 100 cases of EVH; conversion ratios to OVH less than five percent and similar experience within OVH.

Three studies reviewed vein repairs within the graft patency discussion section ascertaining with significance experienced practitioners inflict fewer injuries to the LSV (Desai et al 2011, Kiani et al 2012, Erden and Gultekin 2021). One study looked specifically at harvesting practitioners with no experience exposed to a conventional training programme versus a bespoke programme developed at the University Hospital of South Manchester NHS Foundation Trust (Krishnamoorthy et al 2012). Within the learning curve it was demonstrated with significance that a structured programme such as the Manchester Endoscopic Learning Tool (MELT) reduced vein graft injuries and had no conversions to OVH compared with the conventional programme ($P < 0.001$) (Krishnamoorthy et al 2015). Conversion rates to OVH were also reviewed in two other studies reviewing the learning curve between practitioners with less than 100 case experience versus over 900 cases and in both studies, there were no conversions in either group (Desai et al 2011 and Kiani et al 2012).

Within the context of previous systematic reviews conducted between 2017 – 2022, experience of the harvesting practitioner was not transparent within the methods section, however all four reviews discussed the experience of the harvesting practitioner would affect the patient outcomes and the need for further studies to include experienced operators (Kodia et al 2018, Li et al 2019, Yokoyama et al 2021, Vuong et al 2022). It is beyond the scope of this review to establish an exact case load to determine competence, but inferred data suggests a case load of 100 cases, or more is optimal to improving learning curve associated vein injuries, but this may be lower.

Graft patency and intimal wall remodelling (Table 3):

Within early studies, vein graft failure of the LSV harvested by EVH has been associated with poorer outcomes such as higher mortality and myocardial infarction rates leading to the reduced adoption of EVH within the UK (Lopes et al 2009, Zenati et al 2011, Soni et al

2019). The controversy surrounding these studies was further compounded with the study by Andreasen et al (2015) showing reduced vein graft patency rates with EVH whilst using practitioners, with harvesting experience of 30 cases only (P<0.001). The study by Andreasen et al (2015) did not successfully meet the critical appraisal requirements for this thematic review due to limitations within the study inciting bias. Recent systematic reviews between 2017- 2022 have conflicting outcomes on vein graft patency regarding the use of EVH, but four systematic reviews acknowledge the need to use experienced practitioners to prevent bias of the outcomes (Kodia et al 2018, Li et al 2019, Yokoyama et al 2021, Vuong et al 2022). Due to heterogeneity within the studies, this thematic review produced results from three studies specifically analysing vein graft patency rates with the experience of the harvesting practitioner ranging between 30 to 900 cases (Yun et al 2005, Desai et al 2011, Tamura et al 2020). Whilst statistical significance was not demonstrated in inferior patency rates within EVH (P = 0.584; P = 0.783) the trending data reported decreased patency rates and vein wall remodelling when vein injuries occurred more than four times per graft (Desai et al 2011, Kiani et al 2012, Tamura et al, 2020). Vein graft injuries and intimal wall remodelling were analysed within two studies comparing EVH and OVH (Yun et al 2005, Krishnamoorthy et al 2012), with a further four studies comparing EVH only between experienced and inexperienced practitioners (Desai et al 2011, Kiani et al 2012, Krishnamoorthy et al 2015, Erden and Gultekin 2020). Experienced practitioners demonstrated less vessel wall injury and fewer vein repairs with significance in three studies where the experience of the harvesting practitioner was over 250 cases (P = 0.0012) and analysing under 100 case experience against over 900 cases (P = 0.05; P = 0.03; P = 0.02; P = 0.012) (Krishnamoorthy et al 2017b, Desai et al 2011, Kiani et al 2012). Whilst vein repairs may not directly elicit a relationship with vein graft patency rates, vein bruising and endothelial damage to the intimal wall causes positive remodelling reducing the diameter of the lumen and can be affected by clot formation occlusions (Kiani et al 2012, Wolny et al 2021).

Limitation of the studies reviewed:

There was a lack of sufficiently powered studies and long term follow up of graft patency beyond six months to make clinical recommendations as part of standard practice without the need for further research. High quality histological studies with clinical outcomes can be expensive which requires large sample size of patients and manpower but there is a need for the potential funders to invest on these studies to obtain good quality conduit analysis which will yield better post-surgical patient outcomes.

Conclusion:

The learning curve period may not be as recommended by NICE (2014) as 20 cases to be enough to attain the proficiency within EVH. Current evidence suggests that experience over 100 cases of EVH has demonstrated to reduce vein repairs, haematoma formation in between the layers of the vein, bruising of the vein and conduit related graft failure at the six month point (Kiani et al 2012). Vein conduit failure can be multifactorial such as technical issues like thrombosis, intimal hyperplasia, small target vessel size, poor target vessel motion, grafting to chronically occluded arteries (Sabik et al, 2011). However, one of the major causes is endothelial damage caused during surgery that can be avoided and has been demonstrated to be less significant with practitioners with over 100 cases of experience whereby vein conduit injuries occur less (Desai et al 2011 and Kiani et al 2012). However, the learning curve period has not been defined precisely within this review and may be subjective to the individual learners' dexterity, but previous experience of OVH and SBT may reduce the learning curve of EVH. Importantly, obtaining the detailed knowledge of anatomy, physiology, tissue handling, conduit injury related complications and instrument dexterity can support the harvesters' decision making on harvesting techniques. Adopting a formalised structured training programme to address these learning outcomes enhances the harvesting practitioner's confidence during the initial learning curve period and has demonstrated to achieve less injury to the vein conduit in comparison to conventional training methods (Krishnamoorthy 2015 and 2016). Vein conduit injuries can be unavoidable on high-risk patients but there is an increased risk during the learning curve period. Therefore, it is imperative to consider the exclusion of these patients during the learning curve until proficiency is attained (Krishnamoorthy et al 2016).

Whilst the experience or the effects of anastomosing the LSV to the target vessel were not studied in this review, it forms part of the outcomes of the themes identified within this review and should be considered when conducting further research.

In summary, we recommend that researchers publish harvesting techniques outcome data in relation to the level of the experience of both the harvesting practitioner and the operating surgeon, to better understand the association between the outcomes in CABG surgery and conduit harvesting techniques.

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Figure 1. PRISMA 2020 flow diagram for new systematic reviews (Paige et al 2021).

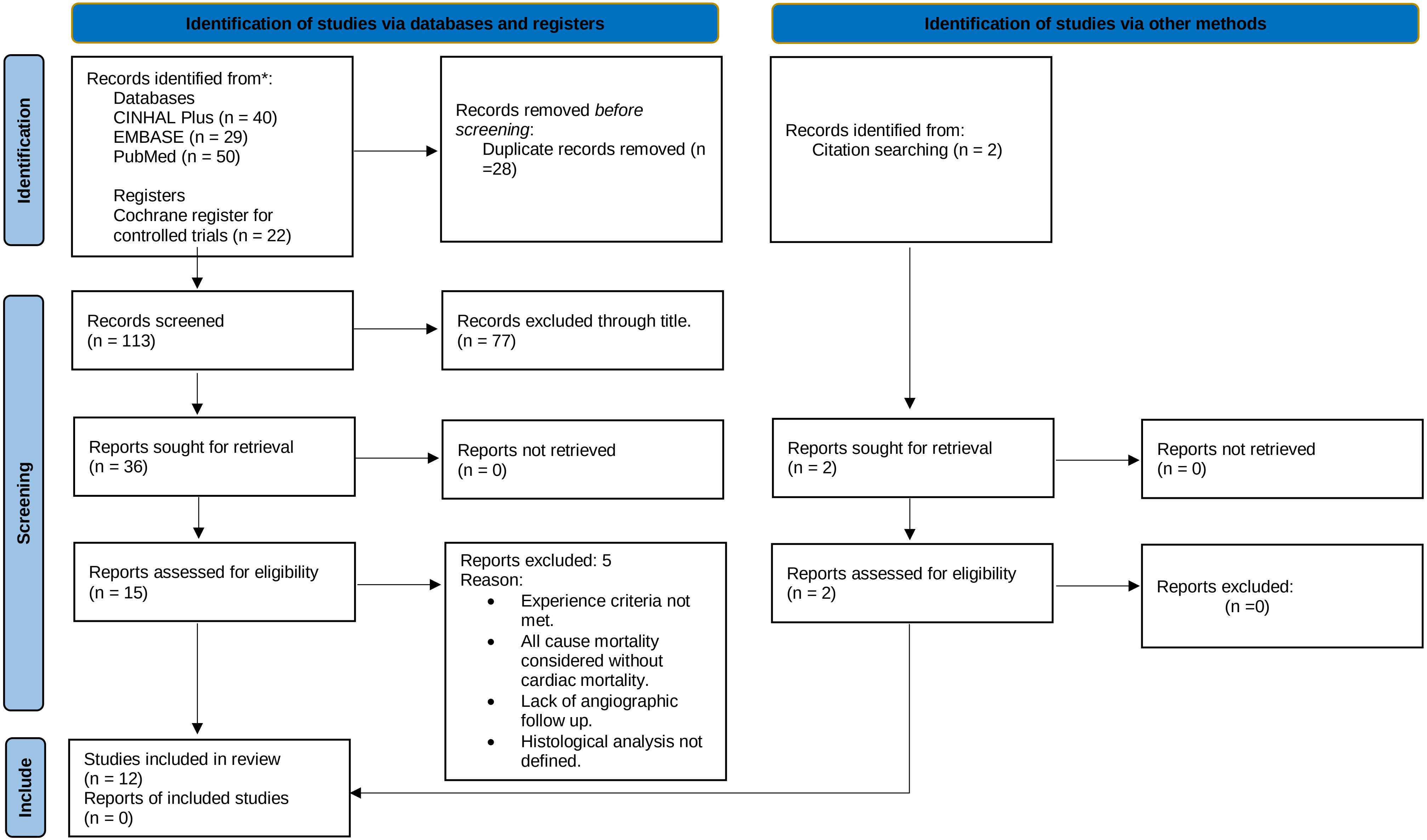

Table 1. CASP question 7 and 8 results and discussion.

Author.	**Article.**	**Design and Sample size.**	**Comparators.**	**Themes.**	**Outcomes.**	**Limitations.**
Yun et al, 2005.	Randomised trial of endoscopic versus open vein harvest for coronary artery bypass grafting: Six-month patency rates.	RCT. 200 participants.	EVH. OVH.	Leg wound complications. Six-month graft patency rates.	Leg wound complications reduced in EVH group (p = 0.014). Vein graft occlusion rates comparable between EVH and OVH at 6 months (p = 0.584). Vein graft repairs higher in EVH group (28 repairs versus 5).	Sample size may be affected with the lack of angiographic follow up unable to detect any significant difference between the two harvesting methods.
Desai et al, 2011.	Impact of the learning curve for endoscopic vein harvest on conduit quality and early graft patency.	Non-randomised prospective cohort study. 95 participants.	EVH. OVH. Experienced operators. Inexperienced operators.	Composite injury score for conduits harvested. Histopathological analysis of conduit at day 5.	Vein wall injuries decreased within the experienced group (p = 0.001). Graft patency at day 5 comparable between groups (p = 0.552).	Small sample size.
Kiani et al, 2012.	Venous grafts procured during the learning curve for endoscopic veins harvested show compromised vascular remodelling.	Non-randomised prospective cohort study. 85 patients.	EVH. Experienced operators. Inexperienced operators.	Optical coherence tomography analysis of conduit wall injury. Computed tomography angiography of	Day 5 remodelling of vein graft greater in the novice group (p< 0.001). Intimal injuries around the ostia of	Small sample size. Lack of angiographic follow up to report on vein graft occlusion and discussion of

				vessels at day 5 and 6 months. Relationship of graft wall injury and patency.	tributaries higher in novice group (p = 0.014). Vessel diameter and relationship with shear force statistically significant (p< 0.001). SVG lumen diameter at 6 months reflected by the intraoperative intimal injury and post-operative day 5 remodelling (p< 0.041; p = 0.005).	perioperative findings.
Krishnamoorthy et al, 2012.	A randomised study comparing three groups of vein harvesting methods for coronary artery bypass grafting: endoscopic harvest versus standard bridging and standard open techniques.	RCT pilot study. 150 participants.	EVH. OVH. SBT.	Post-operative pain. Leg wound complications. Length of stay. Vein wall injury.	Reduced pain in EVH group (p> 0.001). Increased haematoma formation in EVH group (p> 0.001). Reduced length of stay EVH group (p>0.002). Increased vein repairs in EVH group (P= 0.014).	Pilot study design with small sample group and lack of statistical power. Experience of EVH low in comparison to the other two techniques.
Chernyavskiy et al, 2015.	Comparative results of endoscopic and open methods of	Prospective parallel group trial. 228 participants.	EVH. OVH.	Leg wound complications.	Post-operative complications lower	Short follow up period of 7 days only.

	vein harvesting for coronary artery bypass grafting: a prospective randomised parallel-group trial.			Post-operative pain. Histopathological analysis of vein wall injury.	in the EVH group (p> 0.01). Post-operative pain lower in EVH group (p> 0.003). Lower leg wound complications in EVH group (p= 0.001). Vein dissection isolated to EVH group (p= 0.002). Vein wall damage comparable between EVH and OVH (p = 0.65).	Long term graft patency follow up not conducted.
Andreasen et al, 2015.	Decreased patency rates following endoscopic vein harvest in coronary artery bypass surgery.	Retrospective cohort study. 129 participants.	EVH. OVH.	MACE. Vein graft patency follow up at median 6.3 years.	Vein graft failure higher within EVH group (p= 0.001). Recurrence of angina lower in EVH group (p= 0.44). MI, cardiac mortality, and all-cause mortality lower in EVH group (p = 0.11; p = 0.24; p = 0.15). Statistical significance considered in this study as p> 0.5.	Small sample group. Research not originally powered to study the end points of long-term clinical outcomes of EVH and OVH. Follow up analysis of only 50% of the original sample group.

Krishnamoorthy et al, 2015.	Does the introduction of a comprehensive structured training programme for endoscopic vein harvesting improve conduit quality? A multicentre pilot study.	Non - randomised prospective cohort study. 112 vein samples 14 practitioners.	EVH. MELT training programme. Conventional training programme.	Conduit injury. Practitioner stress.	Vein repair higher is CST group (P< 0.001). Greater haematoma formation in CST group (p> 0.001). Practitioner stress levels higher in CST group (p> 0.001).	Pilot study design. Small sample size. Vein injury not assessed by histological analysis or computed tomography. Long term clinical outcomes of vein wall injury not assessed.
Krishnamoorthy et al, 2017.	Study comparing vein integrity and clinical outcomes in open vein harvesting and 2 types of endoscopic vein harvesting for coronary artery bypass grafting.	RCT. 300 participants.	EVH open tunnel with CO2. EVH closed tunnel with CO2. OVH.	Histological analysis of vein wall injury. MACE. Cost effectiveness analysis.	Endothelial integrity preserved less in the EVH group (p<0.001). Endothelial stretching higher in EVH group (p= 0.01). MACE at 4 years comparable between EVH and OVH (p= 0.61).	Experience of OVH significantly greater than EVH. Single experience practitioner. Power statistic required 1000 participants in each arm for the detection of small differences in clinical outcomes.
Krishnamoorthy et al, 2017b.	Randomised study comparing the effect of carbon dioxide insufflation on veins using 2 types of endoscopic and open vein harvesting.	RCT. 301 participants.	EVH open tunnel with CO2. EVH closed tunnel with CO2. OVH.	Endothelial integrity.	Endothelial vein integrity preserved less in the EVH group (p= 0.012). Endothelial stretching higher in the EVH group (p= 0.003).	Experience of OVH significantly greater than EVH. Role of heparin use within one group only and the effects on clinical outcomes are unknown.

Tamura et al, 2020.	The back approach technique of endoscopic saphenous vein harvesting in coronary artery bypass grafting.	Retrospective cohort study. 169 participants.	EVH. OVH.	Vein graft patency rates. Leg wound complications. Length of stay. Learning curve of EVH.	SVG patency rates comparable between EVH and OVH with no statistical significance.	Single centre. Small sample group.
Krishnamoorthy et al, 2021.	A multicentre review comparing long term outcomes of endoscopic vein harvesting versus open vein harvesting for coronary artery bypass surgery.	Retrospective cohort study. 27,024 participants.	EVH. OVH.	Mortality. Post-operative complications. Length of stay. Repeat revascularisation.	Reduced risk of mortality in EVH group at 4 years ($p<0.007$). Leg wound infections reduced in EVH group ($p< 0.001$). Post-operative pulmonary complications higher in EVH group ($p< 0.001$). Revascularisation comparable between EVH and OVH.	Lack of angiographic analysis for the entire sample group.
Erden and Gultekin, 2021.	Learning process and results in endoscopic saphenous vein harvesting technique.	Retrospective cohort study.	EVH. Experienced operators. Inexperienced operators.	Vein graft injury. Learning curve for EVH.	After 20-case learning experience vein injuries reduced ($p>0.001$).	Single centre. Small sample group.

Table 2a. Learning curve associated injuries to the LSV.

Author.	Desai et al, 2011				Kiani et al, 2012.			Krishnamoorthy et al, 2012.		
Study design.	Non-randomised prospective pilot.				Non-randomised prospective trial.			RCT pilot.		
Sample size and allocation.	95				85			150(50 participants SBT).		
	OVH 10	EVH 30		EVH 55	EVH 30	EVH 55		OVH 50	EVH 50	
Experience of harvesting practitioner.	NR	<100		>900	EVH <100	EVH >900		OVH >1000	EVH 20	
Intimal wall integrity/injury.	OVH NR	EVH 5.24± 4.34	EVH 3.42± 3.19	P 0.03	EVH 2.48	EVH 1.76	P 0.02	OVH NS	EVH NS	P NS
Adventitial injury	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Vein dissection.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Vein repairs	NS				<4 injuries lumen diameter day 5, 3.09mm. >4 injuries lumen diameter at day 5, 2.88mm. >4 injuries at 6 months positive remodelling.		<0.249 0.05	0	17	0.014
Vein bruising	NS				NS	NS	NS	NS	NS	NS
Conversion to SBT.	NS				NS	NS	NS	NS	NS	NS
Conversion to OVH	NS	0	0	0	0	0	NR.	NS	NS	NS

NR – Not reported on within the study. NS – Not analysed within the study.
CST – Current standard training. MELT – Manchester Endoscopic Learning Tool.

Table 2b. Learning curve associated injuries to the LSV.

Author.	Krishnamoorthy et al, 2015.				Erden and Gultekin, 2021		
Study design.	Non-randomised prospective pilot study.				Retrospective cohort study.		
Sample size and allocation.	112				40		
	EVH CST 56	EVH MELT 56			EVH 20	EVH 20	
Experience of harvesting practitioner.	OVH >150	EVH 0			EVH 0	EVH 20	
Intimal wall integrity/injury.	EVH CST NS	EVH MELT NS	P NS		EVH NS	EVH NS	P NS
Adventitial injury	54(96.4%)	6(10.7%)	<0.001		3	0	0.712
Vein dissection.	7(12.5%)	1(1.8%)	0.061		NS	NS	NS
Vein repairs	42(75%)	12(21.4%)	<0.001		8	2	<0.001
Vein bruising	54(96.4%)	6(10.7%)	<0.001		burns	NS	NS
Conversion to SBT.	10(17.9%)	3(5.4%)	0.074		NS	NS	NS
Conversion to OVH	10(17.9)	0	0.001		NS	NS	NS

NR – Not reported on within the study. NS – Not analysed within the study.

CST – Current standard training. MELT – Manchester Endoscopic Learning Tool.

Table 3a. Graft patency rates and intimal wall remodelling.

Author.	Yun et al, 2005			Desai et al, 2011				Kiani et al, 2012.		
Study design.	RCT.			Non-randomised prospective pilot trial.				Non-randomised prospective trial.		
Sample size and allocation.	200			95				85		
	OVH 100	EVH 100		OVH 10	EVH 30		EVH 55	EVH 30	EVH 55	
Experience of harvesting practitioner	OVH NR	EVH 300		NR	<100		>900	EVH <100	EVH >900	
Patency rates	OVH (71) 170grafts 119(70%)	EVH (73) 166 grafts 113(68%)	P 0.584	>4 injuries patency rates at day 5, 67% <4 injuries patency rate at day 5, 96%			P 0.05	<4 injuries lumen diameter day 5.,3.09mm. >4 injuries lumen diameter at day 5, 2.88mm >4 injuries at 6 months positive remodelling.		P <0.249 0.05
Occlusion.	30(18%)	36(22%)	0.584	NS	6.45%	4.34%	0.34	NS	NS	NS
Severe disease.	21(12%)	17(10%)	0.584	NS	NS	NS	NS	NS	NS	NS
Vein dissection.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Intimal wall integrity/injury.	NS	NS	NS	NS	5.24±4.34	3.42±3.19	0.03	2.48	1.76	0.02
Vein repairs	5	28	NR	NS	1.72±1.79	1.11±1.05	0.05	5.37 per graft	3.31 per graft	0.014
Patient demographics	Congestive heart failure a predictor of occlusion and disease.		0.007	Similar baseline patient characteristics.			NR	Unstable angina more prevalent within the expert group.		0.001
Follow up period.	6 months.			Postoperative day 5.				Postoperative day 5 angiogram.		

NR – Not reported on within the study. NS – Not analysed within the study

Table 3b. Graft patency rates and intimal wall remodelling.

Author.	Chernyavsky et al, 2015.			Krishnamoorthy et al, 2017a				Krishnamoorthy et al, 2017b			
Study design.	Prospective randomised.			RCT				RCT			
Sample size and allocation.	228			300				301			
	OVH 115	EVH 113		OVH 101	EVH Open 100	EVH Closed 100		OVH 101	EVH open 100	EVH closed 100	
Experience of harvesting practitioner	OVH >100	EVH >100		OVH >2000	EVH >250			OVH >2000		EVH >250	
Patency rates	OVH NS	EVH NS	P NS	OVH NS	EVH open NS	EVH closed NS	P NS	OVH NS	EVH Open NS	EVH closed NS	P NS
Vein dissection.	0	5(6.4%)	0.02	NS	NS	NS	NS	NS	NS	NS	
Intimal wall integrity.	30(36.1%)	23(29.4%)	0.37	Proximal95.75% Distal 95.38%	91.63% 91.75%	91.5% 92.25%	<0.001 0.07	Normal 54% Mild 35% Moderate 8% Severe 0	34% 38% 13% 13%	39% 34% 20% 5%	0.0012
Vein repairs	NS	NS	NS	NS	NS		NS	NS	NS	NS	
Patient demographics	Atherosclerosis in lower extremities higher in EVH group.		0.008	Open tunnel EVH and OVH had higher smoking history than closed tunnel EVH. BMI and left main stem disease higher in the closed tunnel EVH.			0.03 0.04	Slightly higher BMI, Left main disease and current smoking in the EVH closed group.		NR	
Follow up period.	7 days.			3-month intervals until 12 months. Subsequent follow up at 18, 24,36 and 48 months.				Histological sampling postoperatively.			

NR – Not reported on within the study. NS – Not analysed within the study.

Table 3c. Graft patency rates and intimal wall remodelling.

Author.	Tamura et al, 2020			Krishnamoorthy et al, 2021.		
Study design.	Retrospective cohort.			Retrospective cohort.		
Sample size and allocation.	169			27,024		
	OVH 125	EVH 44		OVH 13,230		EVH 13,794
Experience of harvesting practitioner	OVH NR	EVH >20		OVH 100		EVH 50
Patency rates	OVH 94.7%	EVH 95.6%	P 0.763	OVH 87/203 42.9% Occlusion rate	EVH 70/160 43.8% Occlusion rate	P 1
Vein dissection.	NS	NS	NS	NS	NS	NS
Intimal wall integrity/injury	NS	NS	NS	21 (0.2%) Revascularisati on for graft occlusion	8 (0.1%) Revascularisati on for graft occlusion.	NR.
Vein Injury/ repairs	NS	NS	NS			
Patient demographics	Diabetes in the EVH groups statistically significant.		0.026	Above 10% difference in 7 0f 25 patient variables. Addressed using propensity matching.		NR.
Follow up period.	Postoperative angiograph.					

NR – Not reported on within the study. NS – Not analysed within the study.