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Is totally endoscopic coronary artery bypass safe, feasible and effective?

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Abstract

A best evidence topic was written according to a structured protocol. The question addressed was whether totally endoscopic coronary artery bypass (TECAB) is safe, effective and feasible. A total of 171 papers were found, of which eight represented the best evidence. The authors, date, journal, study type, population, main outcome measures and results are tabulated. The da Vinci robotic system was utilized in seven retrospective studies and one multicentre prospective trial, comprising 724 patients undergoing TECAB. Patient-related outcomes, including the incidence of major adverse cardiac events, graft patency and survival, were investigated. From the studies evaluated, TECAB appears to be safe operation with low complication rates and excellent early- and mid-term graft patencies. The incidence of internal thoracic artery injury was documented in four studies and ranged from 0 to10%. Re-exploration for bleeding was necessary in 1–15% of patients. Conversion to open techniques was performed in 0–24% of cases. There was no in-hospital mortality in the majority of studies, but this reached 2.1% in a large series of 228 patients. Target-vessel reintervention rates varied between 0 and 12.1% according to the institutional experience. Pre- and post-discharge graft patencies were excellent at 93–100 and 92–100%, respectively. Intraoperative variables, such as time taken for internal thoracic artery harvest, anastomosis, cross-clamp, cardiopulmonary bypass (CPB) and the overall operation were as follows: internal thoracic artery harvest time (range 5–187 min), anastomosis time (range 6–82 min), cross-clamp time (range 30–223 min), CPB time (range 41–268 min) and operative time (range 84–600 min). TECAB is a technically demanding and time-consuming procedure associated with a significant learning curve. Proctoring and structured training programmes are currently supported by European and international societies to encourage wider uptake of the procedure. In conclusion, TECAB represents a feasible alternative to conventional coronary artery bypass in selected patients. It is associated with low morbidity and excellent mid-term graft patency. Larger, prospective and multicentre trials are required to assess the long-term and patient-reported outcomes of TECAB.

Keywords: TECAB • CABG • Robotic • Endoscopic • Coronary artery • Cardiac

INTRODUCTION

A best evidence topic was constructed according to a structured protocol. This is fully described in the ICVTS [1].

THREE-PART QUESTION

In [patients undergoing totally endoscopic coronary artery bypass surgery], is [robotic assistance] associated with a high rate of [postoperative complications]?

CLINICAL SCENARIO

You attend a multidisciplinary meeting to discuss the surgical management of a 67-year old male with single-vessel disease of the left anterior descending (LAD) artery. Minimally invasive direct coronary artery bypass (MIDCAB) is suggested as the operation of choice, owing to excellent graft patency and survival outcomes. Totally endoscopic coronary artery bypass (TECAB) is mentioned as another suitable technique, but there are concerns regarding the long-term results of this procedure. You perform a literature search to investigate the safety, feasibility and efficacy of TECAB.

SEARCH STRATEGY

Medline 1948 to March 2011 using the Ovid interface. [robotic cardiac surgery.mp OR robotic coronary artery bypass.mp OR robotic CABG.mp OR endoscopic cardiac surgery.mp OR endoscopic coronary artery bypass.mp OR endoscopic CABG.mp].

SEARCH OUTCOME

The search strategy identified 187 papers, of which eight provided the best evidence to answer the clinical question. Only TECAB papers published within the last 10 years were selected (Table 1).

RESULTS

In most studies evaluated, patients referred to first-time single-vessel coronary artery bypass graft (CABG) were eligible for TECAB. Exclusion criteria included previous thoracic surgery, morbid obesity, haemodynamic instability, acute myocardial infarction or stroke, renal failure, severe respiratory compromise and peripheral vascular disease, precluding single-lung ventilation and femoral cannulation, respectively.

In the Gao *et al.*' [2] retrospective study of 58 single-vessel TECAB patients, there was no ITA injury. Two cases were converted to MIDCAB (3%), with one re-exploration (1.7%) for bleeding. Graft patency predischarge and at 3, 6 and 12 months was 100%.

Argenziano *et al.* [3] reported a 5.9% incidence of major adverse cardiac events (MACEs) in their multicentre prospective trial of 85 single-vessel TECAB patients. Five patients (6%) required conversion to sternotomy following internal thoracic artery (ITA) injury, anastomotic bleeding or poor intraoperative graft flow. Target-vessel reintervention was necessary in four patients (4.7%). Three-month angiography demonstrated anastomotic occlusion in two cases and >50% stenosis in four cases. Nevertheless, overall freedom from reintervention or graft failure was 91%.

de Cannière *et al.* [4] investigated 228 patients, 90% with single-vessel disease, undergoing on- or off-pump TECAB in a multicentre retrospective study. Twenty-seven were converted to non-robotic techniques in the on-pump group, due to cannulation issues in 55%. The majority of 37 off-pump conversions were attributed to patient-related factors and anastomotic bleeding. All-cause mortality was lowest with on-pump at 2.1%. Six patients (2.6%) required target-vessel reintervention. Overall efficacy, as defined by angiographic patency and stress echocardiography, was 97%.

In their retrospective study, Dogan *et al.* [5] demonstrated 100% predischarge graft patency among the first 22 (of 45) patients undergoing single- or double-vessel TECAB. Ten required conversion to left mini-thoracotomy or sternotomy. Other complications included anastomotic bleeding (4.4%), ITA injury (2.2%), myocardial infarction (2.2%) and retrograde aortic dissection (2.2%).

Kappert *et al.* [6] retrospectively analysed 41 patients with high-grade LAD lesions; the first eight underwent arrested-heart TECAB, whereas the remainder had beating-heart procedures. Fourteen patients underwent postoperative angiography and 5 (12.2%) required LAD reintervention. Two suffered myocardial infarction within the follow-up period, but neither was attributed to the bypassed target vessels. There was no in-hospital mortality, and overall survival was 92.7%, with 82.9% freedom from MACCE.

Three-month graft patency was 92% among 13 single-vessel TECAB patients (11 off-pump) in the retrospective study by Mishra *et al.* [7]. There was one reoperation for bleeding; no other complications or mortality were reported.

Srivastava *et al.* [8] retrospectively analysed 214 patients undergoing single-vessel, double-vessel or triple-vessel beating-heart TECAB. There were no reported ITA injuries. Five patients (2.1%) in the single-vessel and 12 (5%) in the double-vessel group required conversion to mini-thoracotomy; two (1%) required re-exploration for bleeding. Complications included new-onset atrial fibrillation in 10% and postoperative angina in 1%. In 182 of a total of 239 grafts (82%) evaluated, 100% were patent. Overall clinical freedom from graft failure and reintervention was 98.6%.

Bonatti *et al.* [9] retrospectively investigated 40 patients undergoing arrested-heart TECAB for single-vessel disease using remote-access perfusion CPB. Undesirable technical issues arose in 20 cases (50%), including remote-access perfusion problems (23%), anastomotic bleeding (18%), ITA injury (10%) and port bleeding (8%). Revision was necessary in 30% (6 of 20) in which technical challenges arose. Nevertheless, there was no operative mortality or target-vessel reintervention, and cumulative survival was 100%.

Many studies describe a significant TECAB 'learning curve', reflected by extended operating times (3–5 h) for single-vessel bypass, but exceeding 8 h for triple-vessel procedures. However, with increasing surgical experience, there is a general trend towards shorter ITA harvest, anastomosis, cross-clamp and cardiopulmonary bypass times.

CLINICAL BOTTOM LINE

The studies examined are generally of low evidence level and limited by small patient populations, short durations of follow-up and lack of comparison against alternatives such as MIDCAB. In their 2005 guidance, the National Institute for Clinical Excellence (NICE) highlighted the inadequate safety and efficacy data regarding TECAB (http://publications.nice.org.uk/totally-endoscopic-robotically-assisted-coronary-artery-bypass-grafting-ipg128). However, both on- and off-pump TECAB demonstrate promising safety outcomes, with a low incidence of MACE. TECAB represents a major paradigm change, demanding a different, complex skill set from open cardiac surgery. The complications observed here may reflect early experience, associated with a substantial learning curve. Indeed, intraoperative conversion rates may decline with increasing experience. Furthermore, conversion does not compromise graft patency, which remains excellent in the short- and mid-terms. Careful patient selection, target-vessel assessment and team-training are mandatory. Although TECAB is time-consuming and technically demanding, it is feasible. Technological developments, e.g. in anastomotic devices and endoscopic stabilizers, will further enhance this procedure. Proctoring and the provision of structured educational programmes will facilitate the wider adoption of TECAB within the cardiac surgical community. In conclusion, TECAB is a safe alternative to conventional CABG, offering excellent graft patency in highly selected patient groups. Larger, prospective and multicentre trials are required to confirm the encouraging results of TECAB and report on patient-reported outcomes, which remain to be addressed.

Table 1: Best evidence papers

Author, date and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
Gao *et al*. (2011), J Thorac Cardiovasc Surg, China [2] Single-centre, retrospective study (level 2b)	58 patients (mean age 56.97 ± 9.7 years) da Vinci surgical system utilized 16 patients underwent a hybrid procedure Follow-up by computed tomography angiography at 3, 6 and 12 months	Incidence of ITA injury Re-exploration for bleeding Conversions In-hospital mortality Target-vessel reintervention Mean ITA harvest time Mean anastomosis time Mean operation time Predischarge graft patency Post-discharge graft patency	0/58 (0%) 1/58 (1.7%) 2/58 (3%) 0/58 (0%) 0/58 (0%) 31.3 ± 10.5 min (18–55) 11.3 ± 4.7 min (5–21) 264.8 ± 65.6 min (150–420) 100% 100%	TECAB is a safe procedure in selected patients, producing excellent short- and mid-term graft patency results There is a substantial learning curve Careful consideration of patient comorbidities and the location, course and quality of the target vessel are needed
Argenziano *et al*. (2006), Ann Thorac Surg, USA [3] Multicentre, prospective trial (level 1b)	85 patients (mean age 58.4 years) da Vinci surgical system utilized Follow-up with coronary angiography at 3 months	Incidence of MACE All-cause mortality Perioperative myocardial infarction Target-vessel reintervention Incidence of other adverse events Conversions Reoperation for bleeding Mean ITA harvest time Mean anastomosis time Mean cross-clamp time Mean CPB time Mean operation time 3-month graft patency Overall freedom from reintervention or graft failure	5.9% overall 0/85 (0.0%) 1/85 (1.1%) 4/85 (4.7%) 3/85 (3.5%) 5/85 (6%) 3/85 (3.5%) 60 ± 24 min (26–187) 28 ± 11 min (14–82) 71 ± 26 min (30–140) 117 ± 44 min (41–254) 353 ± 89 min (200–600) Anastomotic occlusion in two cases; ≥50% stenosis in four cases 91%	TECAB can be performed with acceptable safety and efficacy but requires participation in a structured training programme
de Cannière *et al*. (2007), J Thorac Cardiovasc Surg, Belgium [4] Multicentre, retrospective study (level 2b)	228 patients (mean age 59.2 ± 10.1 years) da Vinci surgical system utilized Patients were categorized to groups: A (on-pump, 90 patients), B (off-pump, 74 patients), or C (conversions, 64 patients)	6-month freedom from MACE All-cause mortality Perioperative myocardial infarction (<7 days) Target-vessel reintervention	No significant difference between groups Overall: 5/228 (2.1%) A: 1/90 (1.1%) B: 2/74 (2.2%) C: 2/64 (2.31%) Overall: 2/228 (0.9%) A: 1/90 (1.1%) B: 1/74 (1.2%) C: 0/74 (0.0%) Overall: 6/228 (2.6%) A: 2/90 (2.2%) B: 3/74 (4.1%) C: 0/74 (0.0%)	Patency rates and 6-month freedom from MACEs were acceptable Both on- and off-pump TECAB are feasible, safe and effective procedures Conversion decreases with time, and does not adversely affect the outcome

Continued

Table 1: (*Continued*)

Author, date and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
	216 patients were followed up at 6 months	Number of grafts with <50% stenosis in distal anastomosis	A: 61/62 (98.4%) B: 35/38 (92.1%) C: 15/17 (88.2%)	
		Negative stress test	A: 23/23 (100%) B: 24/25 (96%) C: 28/28 (100%)	
		Combined procedural efficacy	A: 97% B: 97% C: 97.7%	
Dogan *et al*. (2002), J Thorac Cardiovasc Surg, Germany [5] Single-centre, retrospective study (level 2b)	45 patients (mean age 63 ± 6 years) da Vinci surgical system utilized 37 patients underwent single-vessel (SV) TECAB; 8 patients underwent double-vessel (DV) TECAB	Operative mortality	0/45 (0.0%)	Majority of complications occurred in the first 20 patients, and are associated with the learning curve Bilateral ITA grafting is possible, but is technically challenging and very time-consuming After learning curve, single-vessel TECAB is a straightforward procedure
		Bleeding from anastomosis	2/45 (4.4%)	
		Prolonged cross-clamp time	4/45 (8.9%)	
		Port-access failure	3/45 (6.7%)	
		ITA injury	1/45 (2.2%)	
		Hypovolaemic shock	1/45 (2.2%)	
		Myocardial infarction	1/45 (2.2%)	
		Hypoxic brain damage	1/45 (2.2%)	
		Moderate reperfusion injury	1/45 (2.2%)	
		Retrograde aortic dissection	1/45 (2.2%)	
		Conversions	10 of the first 22 patients; 1 in the last 20 patients	
		Target-vessel reintervention	0/45 (0%)	
		Predischarge graft patency	100% in the first 22 patients	
		Mean ITA harvest time	SV: 65 ± 21 min DV: 118 ± 12.3 min	
		Mean anastomosis time	SV: 18.4 ± 3.8 min DV: 21.2 ± 6.3 min	
		Mean cross-clamp time	SV: 61 ± 16 min DV: 99 ± 55 min	
		Mean CPB time	SV: 136 ± 32 min DV: 197 ± 63 min	
		Mean operation time	SV: 4.2 ± 0.9 h DV: 6.3 ± 1.0 h	
Kappert *et al*. (2008), J Thorac Cardiovasc Surg, Germany [6] Single-centre, retrospective study (level 2b)	41 patients (mean age 60.6 ± 8.9 years) da Vinci surgical system utilized First eight procedures performed on arrested hearts; subsequent procedures were off-pump Mean follow-up period 69 ± 7.4 months	In-hospital survival	41/41 (100%)	Relatively high incidence of target-vessel reintervention following TECAB leaves significant room for improvement Advances in instrumentation and anastomotic technology will produce increasingly reproducible results
		Conversions	0/41 (0%)	
		Overall survival after 5 years	38/41 (92.7%)	
		Myocardial infarction	<6 months: 1/41 (2.4%) >6 months: 1/41 (2.4%)	
		Myocardial infarction and cardiac death	2/41 (4.8%)	
		Repeated revascularization of target vessel	<6 months: 3/41 (7.3%) >6 months: 2/41 (4.8%)	

Continued

Table 1: (*Continued*)

Author, date and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
		Freedom from any major adverse event	75.6%	
		Freedom from MACE	82.9%	
		Freedom from LAD intervention	82.7%	
Mishra *et al*. (2008), Asian Cardiovasc Thorac Ann, India [7] Single-centre, retrospective study (level 2b)	13 patients (mean age 56.3 ± 7.2 years) da Vinci surgical system utilized 11 procedures were off-pump; 2 were performed on an arrested heart Follow-up with coronary angiography at 3 months	Perioperative myocardial infarction	0/13 (0.0%)	Authors advocate early conversion to an open procedure where necessary Authors conclude that beating-heart TECAB is a safe procedure that avoids the harmful effects of CPB
		Reoperation for bleeding	1/13 (7.7%)	
		New-onset atrial fibrillation	0/13 (0.0%)	
		Wound infection	0/13 (0.0%)	
		Postoperative mortality	0/13 (0.0%)	
		Late mortality	0/13 (0.0%)	
		Conversions	0/13 (0.0%)	
		Recurrence of angina	0/13 (0.0%)	
		Target-vessel reintervention	0/13 (0.0%)	
		Graft patency at 3 months	12/13 (92%)	
		Mean ITA harvest time	42 min (35–74)	
		Mean anastomosis time	20–36 min	
		Cross-clamp time	44 min	
		CPB time	64 min	
		Mean operation time	236 ± 45 min (196–296)	
Srivastava *et al*. (2010), Ann Thorac Surg, USA [8] Single-centre, retrospective study (level 2b)	214 patients (mean age 67.9 ± 11.8 years) da Vinci surgical system utilized All procedures performed on a beating heart Single-vessel (SV) TECAB in 139 patients (65%) Double-vessel (DV) TECAB in 68 patients (32%) Triple-vessel (TV) TECAB in 7 patients (3%) 50 patients underwent hybrid procedures Patients followed up for 528 ± 697 days	Mortality	SV: 0/139 (0%) DV:0/68 (0%) TV: 0/7 (0%)	Beating-heart TECAB is a safe and efficacious procedure for selected patients with single- and multivessel coronary disease and offers excellent early clinical and graft patency results
		ITA injury	0/214 (0%)	
		Reoperation for bleeding	2/214 (1%)	
		Ventilatory support >48 h	8/214 (4%)	
		New-onset atrial fibrillation	22/214 (10%)	
		Conversions	SV: 5/214 (2.1%) DV: 12/214 (5%) TV: 0/214 (0%)	
		Postoperative recurrence of angina	3/214 (1%)	
		Graft patency	182/182 (100%)	
		Overall clinical freedom from graft failure and reintervention	98.6%	
		Mean single ITA harvest time	SV: 34.5 ± 13.2 min (16–110) DV: 33.2 ± 8.5 min (23–51)	
		Mean bilateral ITA harvest time	DV: 63.7 ± 14.5 min (40–110) TV: 65.9 ± 13.1 min (44–82)	
			SV: 12.5 ± 5.5 min (6–38)	

Continued

Table 1: (*Continued*)

Author, date and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
		Mean anastomosis time	DV: 13 ± 4.4 min (7–27) TV: 13.1 ± 3.9 min (8–27)	
		Mean operation time	SV: 177.3 ± 52.5 min (84–466) DV: 318.5 ± 97 min (161–616) TV: 523.6 ± 112.3 min (337–682)	
Bonatti *et al*. (2006), J Cardiovasc Thorac Surg, Austria [9] Single-centre, retrospective study (level 2b)	40 patients postoperatively categorized to those without (group 1, mean age 59 years) and with (group 2, mean age 59 years) technical difficulties during TECAB da Vinci surgical system and remote access perfusion CPB utilized All procedures carried out on an arrested heart Follow-up coronary angiography at 3 months in 13 patients from group 1, and 11 patients from group 2	Mortality	Group 1: 0/20 (0%) Group 2: 0/20 (0%)	Overall problem severity level was low and improved with increasing experience Surgical technical challenges translated into significantly increased operative times Technical difficulties may be frequently encountered during TECAB, but patient-related consequences can be minimized with careful observation and intraoperative quality control Freedom from angina and graft patency are not compromised by technical challenges during TECAB
		Patients with technical difficulty	20/40 (50%)	
		Conversions	6/40 (15%)	
		On-table revision	3/40 (8%)	
		Postoperative revision procedure	4/40 (10%)	
		Additional sternotomy	11/40 (28%)	
		Additional mini-thoracotomy	2/40 (5%)	
		ITA injury	4/40 (10%)	
		Epicardial lesion	3/40 (8%)	
		Anastomotic problem	7/40 (18%)	
		Remote access perfusion problem	9/40 (23%)	
		Port bleeding	3/40 (8%)	
		Revision for bleeding	Group 1: 1/20 (5%) Group 2: 6/20 (30%)	
		Atrial fibrillation	Group 1: 2/20 (10%) Group 2: 3/20 (15%)	
		Target-vessel reintervention	0% in both groups	
		Cumulative survival	Group 1: 100% Group 2: 100%	
		Cumulative 3-year freedom from angina	Group 1: 93% Group 2: 100%	
		Anastomotic patency at 3 months	Group 1: 13/13 (100%) Group 2: 11/11 (100%)	
		Distal target-vessel patency at 3 months	Group 1: 13/13 (100%) Group 2: 11/11 (100%)	
		Proximal target-vessel patency at 3 months	Group 1: 13/13 (100%) Group 2: 10/11 (91%)	
		ITA harvest time	Group 1: 48 min (35–85) Group 2: 55 min (37–70)	
		Anastomosis time	Group 1: 35 min (26–66) Group 2: 35 min (23–60)	
		Cross-clamp time	Group 1: 80 min (44–132) Group 2: 71 min (37–223)	
		CPB time	Group 1: 113 min (72–230) Group 2: 134 min (79–368)	

CPB: cardiopulmonary bypass; ITA: internal thoracic artery; LAD: left anterior descending (artery); MACE: major adverse cardiac event; TECAB: totally endoscopic coronary artery bypass.

Conflict of interest: none declared.

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