

A different technique for sutureless coronary bypass grafting

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Abstract: *Introduction:* Many coronary anastomotic devices have been designed to replace manual stitching in coronary surgery; however, interestingly, none of them became widespread. Our aim was to work out an easy and fast endoluminal vessel-to-vessel stent bridge distal anastomotic technique. *Materials and methods:* Ten coronary arteries of eight fresh human hearts were used in this study. The anastomosis was performed with the implantation of a graft vessel into the lumen of the coronary artery by performing stent fixation. The technique is described and photo documented in detail. The durability and the conductivity of the anastomosis were examined with intraluminal endoscopy, functional streaming test, and a coloring of the vessels. *Results:* The anastomosis had great results in all cases. Obstruction, dissection, or dislocation of the vessels was not observable. *Conclusions:* This study confirmed the *ex-vivo* feasibility of the described technique. This method can be an easy, fast, and reliable method applied in the endoscopic distal coronary artery anastomosis surgery. The development of stents adapted to this method and the *in-vivo* testing of this technique are necessary for the future.

Keywords: sutureless anastomotic, coronary stent, coronary surgery, minimally invasive, vessel-to-vessel

Introduction

The tolerability of the coronary revascularization surgery has been improved by various new innovative technologies in the past few decades. The success of the off-pump coronary artery bypass grafting and the increasing number of the minimally invasive approaches (minimally invasive direct coronary artery bypass and totally endoscopic coronary artery bypass) indicate that coronary revascularization procedures will become fully endoscopic operations [1, 2].

Performing the distal coronary anastomosis is the most crucial step in the operation, the success of which influences the outcome of the patients the most. The classical stitching is the gold standard method; however, it is time-

consuming and it requires a lot of experience even in the case of robot-assisted endoscopic approaches.

Many coronary anastomotic devices (C-Port Anastomotic System, Distal Connector, GraftConnector, S² Anastomotic System, and Magnetic Vascular Positioner) have been developed in order to simplify and speed up stitching. Interestingly, although the good functional outcome of surgeries using the above devices is confirmed by many clinical studies, they have not replaced classical stitching. Connecting these instruments to the coronary vessels is technically challenging and requires special, device-related experiences; therefore, their superiority in coronary surgery is questionable [3–19].

The aim of our workgroup was to develop a novel, endoluminal vessel-to-vessel stent bridge distal

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anastomotic technique that does not require extensive experience from the surgeons, and which is highly standardizable and unaffected by the anatomical variations of the coronary and bypass-graft vessels.

Materials and Methods

Ten coronary arteries of eight fresh human cadaveric hearts were involved in this study. The cadavers had been donated to our institute for the purpose of education and medical research. The hearts were removed from the cadavers before the examinations. The ipsilateral internal thoracic artery was used for arterial bypass graft; its collateral branches were closed with ligature or hemoclip. The graft vessels were skeletonized in nine cases (90%).

A coronary stent (TERUMO Tsunami Gold/Kaname, Leuven, Belgium) was introduced in the lumen of the graft vessel from its proximal end. The distal part of the stent was led through the vessel, only its proximal 5 mm remained in it. As a second step, the wall of the coronary artery was incised longitudinally 5-mm long, and the stent-graft vessel complex was introduced into its lumen (Fig. 1a-c). After positioning the stent, the balloon was inflated with the prescribed pressure that pressed the stent and the graft vessel to the wall of the coronary artery and secured the anastomosis (Fig. 1d).

Methods of the anastomosis examination

The applied examination methods are summarized in Table I.

Pressure injection and functional streaming test

The durability and conductivity of the anastomosis was controlled with pressure injection in all cases (100%) and a functional streaming test was performed in one case (10%). After removing the balloon, a silicone tube (inner diameter: 2 mm) was connected to the proximal end of the graft vessel. Physiological saline was injected through the anastomosis with a syringe, and once again using a peristaltic pump. The initial streaming value was 20 ml/min, and it was raised gradually by 20–80 ml/min. The possible signs of leakage were controlled visually during the test.

Intravascular endoscopy

Later, the condition of the inner surface of the vessels was controlled with intravascular endoscopy after performing the anastomosis in one case (10%). We used a 2-mm diameter, 30° rigid endoscope (Olympus A7006, Tokyo, Japan). Before the implantation, the graft vessel was stained with aniline blue (aniline blue; 0.5% acetic acid) for 90 s, and dried at 37 °C for 2 min. This resulted in better visibility during the endoscopic examination.

Examining the supply region of the anastomosis

The coronary artery was injected through the anastomosis with colored latex (Kryolan, Berlin, Germany) in three cases (30%) and with colored methyl-methacrylate (Acifix 190, Darmstadt, Germany) in five cases (50%). The hearts were fixed in 4% formalin solution for 4 weeks after the injection. The subepicardial branches

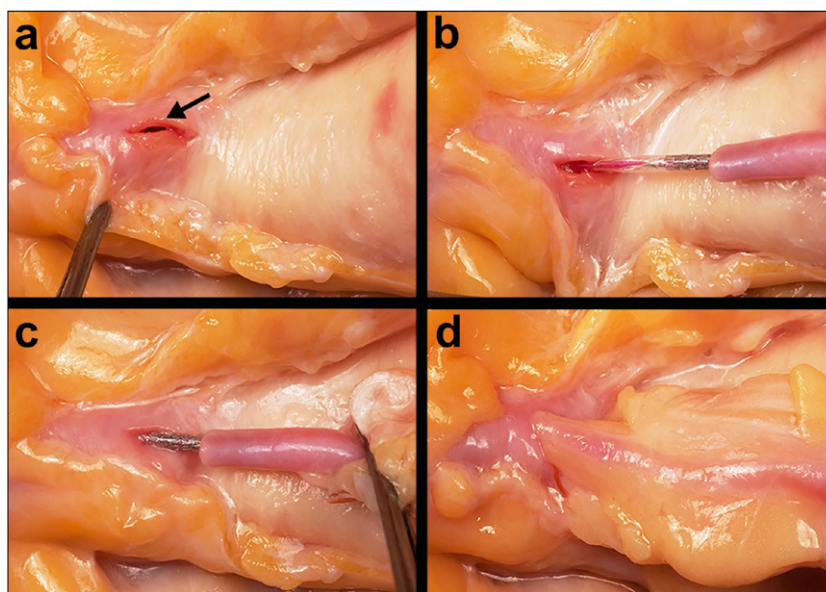


Fig. 1. Steps of the implantation. (a) Performing a 5-mm longitudinal incision on the proximal part of the right coronary artery (black arrow); (b and c) introduction of the graft-applied stent into the lumen of the coronary artery; (d) a successful endoluminal vessel-to-vessel stent bridge anastomosis with a non-skeletonized internal thoracic artery

Table I The implanted stents and the performed investigations

Stent	Diameter of the stent (mm)	Length of the stent (mm)	Coronary artery	Pressure injection (streaming test)	Investigational methods		
					Colored methyl-methacrylate injection and preparation	Colored latex injection and preparation	Intravascular endoscopy
1 TERUMO Tsunami Gold	4.0	10	LCA	X	X		
2 TERUMO Kaname	4.0	12	LCA	X	X		
3 TERUMO Tsunami Gold	4.0	13	CX	X		X	
4 TERUMO Tsunami Gold	4.0	13	LCA	X	X		
5 TERUMO Tsunami Gold	4.0	15	LAD	X			
6 TERUMO Tsunami Gold	4.0	15	LCA	X			
7 TERUMO Kaname	4.0	15	LCA	X	X		
8 TERUMO Tsunami Gold	4.0	18	RCA	X		X	
9 TERUMO Tsunami Gold	4.0	18	RCA	X	X		
10 TERUMO Kaname	3.0	15	RCA	X (X)		X	X

of the stented coronary arteries were prepared after the fixation in three cases (30%).

Preparation of the anastomosis

The anastomosis involving the distal part of the graft and the proximal part of the coronary artery was removed in the eight formalin-fixed cases (80%). The wall of the vessels was windowed in a prolonged rectangular shape to investigate the stent and its relation to the coronary and graft vessels.

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Results

The endoluminal vessel-to-vessel stent bridge anastomosis was quick and easy to perform in all cases (100%). There were no difficulties introducing the stent-graft vessel complex into the coronary artery, nor when inflating the balloon. The securing of the anastomosis was performed safely and correctly in all cases (100%). There was no evidence of a rupture or dissection of the graft. The anastomosis functioned well during pressure injection and streaming test in all cases (100%). There was no observable leakage or dislocation. Intravascular endoscopy provided the intraluminal control of the anastomosis. We found no obstruction in the lumen of the anastomosis, nor any injury on the inner walls of the vessels (*Fig. 2*). The subepicardial branches of the injected coronary artery were filled completely in all cases (100%). Preparing them was easy to perform, verifying the ideal conductivity of the anastomosis (*Fig. 3a*). The different parts of the anastomosis were clearly distinguishable after the windowing (*Fig. 3b*).

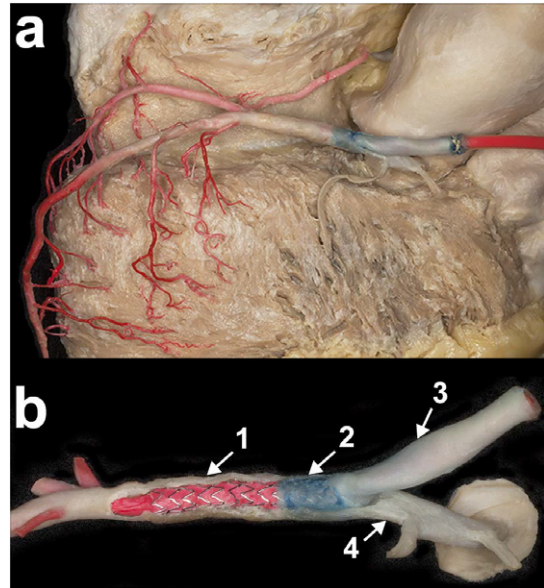


Fig. 3. Dissected specimen after a successfully performed endoluminal vessel-to-vessel stent bridge anastomosis and injection. (a) The subepicardial branches of the coronary artery filled with red-colored latex. (b) The fenestrated anastomosis: (1) distal part of the stent bridge anastomosis, (2) the intracoronary part of the internal thoracic artery, (3) extracoronary part of the internal thoracic artery, (4) proximal part of the right coronary artery

Discussion

Fully endoscopic and robot-assisted surgical approaches became available in the past decades due to the intensive technical development in medicine [1, 2]. However, they did not address the disadvantages of the classic suture technique: the requirement of extensive experience and its time-consuming nature. Many sutureless anastomotic techniques were developed in the past to reduce stitching time and to standardize this crucial step of the operation, but all of them require a specially designed implanting device, and therefore require device-related expertise [3, 4]. Some of them were performed using a complex clip-applier around the distal end of the graft vessel with an array of separate

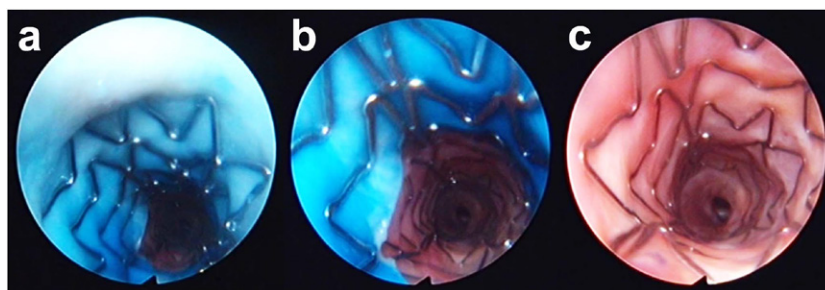


Fig. 2. Intraluminal endoscopic visualization of the endoluminal vessel-to-vessel stent bridge anastomosis. (a) The aniline blue tintured internal thoracic artery with the proximal end of the implanted stent. (b) The transition between the graft and the coronary artery. (c) The distal part of the anastomosis

microclips [5, 6] or an annular connector with hooks [7, 8] as well as staples [9, 10]. To perform end-to-side sutures, there is a T-shaped connector device applied with polytetrafluoroethylene-covered coronary stent [11, 12]. Other ones need a magnetic vascular positioner [13, 14] or an excimer-laser-assisted non-occlusive anastomosis coronary connector [15], both of which are able to replace hand-sewn side-to-side anastomosis. Interestingly, neither of these methods, nor other pilot methods [16–19] became generally accepted in daily clinical practice.

Our workgroup developed a novel sutureless distal coronary anastomosis technique that proved easy, fast, and reliable during the *ex-vivo* tests. Our technique requires no special implanting or fixing instruments: the graft vessel is secured in the coronary artery with the help of a coronary stent, the implantation of which is a routine procedure nowadays. This technique would be easily adaptable to the anatomy of the patient with the modulation of the diameter and the length of the stent, and would utilize the benefits of a hybrid operation room.

In our concept, further development of the instruments will result in a special stent and catheter system that makes accessible the distal end of the harvested internal thoracic artery through a femoral or radial artery puncture. Anchoring the distal end of the graft vessel with the special stent, we will be able to introduce it into the coronary artery. However, we used a longitudinal incision; we are developing a novel coronary puncture method similar to the Seldinger technique. The internal thoracic artery can be harvested using minimally invasive (1–2 cm) thoracoscopic ports without destroying the integrity of the patient's chest. Our method is performable using normal thoracoscopic instruments. There is no need of suturing and therefore it is unnecessary to use robotic assistance.

Limitations of the technique

The endoluminal vessel-to-vessel stent bridge anastomosis technique could be applied especially in cases of critically or totally obstructed coronary arteries. The positioning of the stent-graft complex in the coronary artery is most the crucial step of our technique. The anastomosis should be performed immediately distal to the critical obstruction, because the wall of the graft completely closes the coronary artery in the proximal direction. Imprecise implantation could close the branches of the coronary artery as well as the anastomosis. In case of bleeding from the proximal part of the coronary vessel, its clipping next to the anastomosis should be performed.

Our method, which proved feasible *ex vivo*, is a novel concept for the sutureless coronary anastomosis surgery. The examination of the *in-vivo* feasibility of our technique with specially designed stents is necessary and planned in the future.

* * *

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