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Comparison of conventional electrocautery vs Plasmablade™ for internal thoracic artery harvesting

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ABSTRACT

Objectives: In this study, we aim to investigate whether internal thoracic artery harvesting with the PlasmaBlade™ is more effective and safer than electrocautery in preserving the integrity of the intima and pedicle of the internal thoracic artery.

Patients and methods: Between January 2014 and March 2014, a total of 40 patients were randomized to undergo internal thoracic artery harvesting with the PlasmaBlade™ (group 1; n=20) or electrocautery (group 2; n=20). Internal thoracic artery sections (intima and pedicle) were stained with hematoxylin-eosin, van Gieson's and Masson's trichrome stains. Their integrity was morphologically assessed using the light microscopy.

Results: Histological examination showed that endothelium was well preserved and endothelial injury scores were significantly lower in group 1, compared to group 2 (p=0.020). Bleeding scores for the vessel wall and the pedicle were also significantly lower in group 1, compared to group 2 (p=0.020). The mean injury zone width was significantly shorter in group 1 (0.335 mm and 0.730 mm in group 1 and 2, respectively) (p=0.000).

Conclusion: The PlasmaBlade™ is safer and more effective in preserving the integrity of the intima and pedicle of the internal thoracic artery than electrocautery for internal thoracic artery harvesting in coronary artery bypass grafting. A well-preserved endothelial function may provide higher graft patency rates.

Keywords: Coronary artery bypass surgery; electrocautery; graft harvesting; internal thoracic artery.

After Kolesov performed the first internal thoracic artery (ITA) - left anterior descending artery (LAD) anastomosis,[1] ITA was recognized as the most optimal conduit for coronary artery bypass grafting (CABG). Thanks to its positive effects on early and long-term patency rates and high cardiac survival rates, it has been explicitly suggested by many authors.[2] Despite the developments in transcatheter methods and new generation drug eluting stents, it is still incomparable with other alternative methods in terms of the patency rates of LAD-ITA anastomosis.[3]

Internal thoracic artery has a unique molecular and cellular resistance against atherosclerosis.[4,5] However, endothelial injury during harvesting may activate the coagulation cascade, thereby, leading to early graft thrombosis.[2] Furthermore, the endothelial injury may facilitate the atherosclerotic process, and, as a result, it may cause graft stenosis or occlusion in the long-term.[2] Therefore, the internal elastic lamina must be intact for a high-rate long-term ITA patency.

Internal thoracic artery harvesting with electrocautery has become a standard procedure since first described in 1967.[1] To further increase the utilization of this artery, a variety of topical and systemic vasodilator agents have been proposed and less invasive ITA harvesting techniques have been developed.[4-6]

The PlasmaBlade™ (PEAK Surgical, Inc., Palo Alto, CA, USA) which was developed to cause minimal thermal damage during tissue cutting and coagulation has been introduced as a novel surgical device with pulsed-plasma technology.[7-11]

In this study, we aim to investigate whether ITA harvesting with the PlasmaBlade™ is more effective and safer than conventional electrocautery in preserving the integrity of the intima and pedicle of the ITA.

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PATIENTS AND METHODS

Between January 2014 and March 2014, a total of 40 patients who were hospitalized for CABG were randomized to undergo ITA harvesting with the PlasmaBlade™ (group 1; n=20) or electrocautery (group 2; n=20). The socio-demographic and basic characteristics in respect of accompanying diseases are provided in Table 1.

The primary objective of our study was to find out whether Plasmablade is superior to electrocautery in means of preventing endothelial and perivascular connective tissue injury by histopathologic examination of the ITA samples under light microscope. The study protocol was approved by the Ankara Atatürk Training and Research Hospital Ethics Committee. A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical technique

Internal thoracic artery graft harvesting was initiated with placing the ITA retractor following the median sternotomy. Endothoracic fascia was opened throughout the ITA. The conventional cautery (Valleylab™ Force FX™ monopolar electrocautery, Covidien; Mansfield, Mass) was used at a low-power (diatermy coagulation 20 W). In the other group, the PlasmaBlade™ was used. A special care was taken to avoid dissection, avulsion, or spasm during excision. The subclavian vein was exposed proximally to the ITA and the proximal branches of the ITA were divided. It was distally released up to 1 cm proximal to the bifurcation together with the accompanying satellite veins and fatty tissues. Homeostasis was implemented using hemostatic titanium clips on the ITA branches (SLS-Clip™ System Vitalitec International Inc., Plymouth, Massachusetts, USA). The branches were divided approximately 2 mm distal from the origin of the ITA. Following systemic heparinization for minimum three minutes, the graft was separated from the thoracic wall. The ITA segment was removed from the distal section of the ITA prior to use of the papaverine solution. Then, the papaverine solution is sprayed onto the graft and the ITA was kept in a warm papaverine and physiological saline-impregnated gauze. In our clinic, the bifurcation is kept in place to protect the sternal blood flow and collateral circulation. Approximately 1 cm long distal segment, the ITA is not used prior to bifurcation. The study specimens were obtained removing a 1 cm long ITA tissue proximal to this segment.

Pathological examination

The specimens were fixed in the solution containing 10% buffered formaldehyde. All specimens were sectioned, stained with hematoxylin-eosin (H-E), Masson's trichrome (MTK), and elastic van Gieson (EVG) stains and were examined under the light microscopy (Leica DM6000 B, Leica Microsystems Inc., Buffalo Grove, IL, USA). The specimens stained with MTK were examined to identify the extent of the thermal injury on the collagen in the vascular wall, while the specimens stained with EVG were analyzed to determine the impact of the thermal injury on elastine in the ITA wall. The specimens stained with H-E underwent histological examination.

Endothelial injury, congestion, free bleeding, and the width of the injury zone were evaluated in the histopathological examination under the light microscopy. Scoring systems which were described in previous studies were used.[12,13]

During the histopathological examination, endothelial injury was scored to be 0= no injury, 1= mild injury (slight desquamation in the endothelium, minimal exposure in the basal lamina), 2= moderate injury (intimal or endothelial contusion), and 3= severe injury (endothelial separation), regarding the endothelial cell loss, exposed basal lamina, and intimal and medial edema.

Congestion was scored to be 1, in case of congestion in 30% of the vascular structures; to be 2, in case of congestion in 60% of the vascular structures, and to be 3, in case of 90% or higher congestion of vascular structures.

Free bleeding was scored to be 1, in case of bleeding in less than 10% of the perivascular soft tissue to be 2, if it involves 20-50%, and to be 3, if it is more than 50%.

The width of the injury zone was examined to compare the impact of collateral thermal injury which the PlasmaBlade™ and conventional cautery caused in the soft tissues during dissection.

Statistical analysis

Based on the results of the preliminary power analyses, the obligatory sampling width required for the comparison of the endothelial injury between the groups was calculated as 40 with 20 patients in each

Table 1
The baseline and demographic characteristics of patients

	Group 1			Grup 2			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (years)			60.40±7.94			61.30±8.05	0.724
Sex							0.342
Male	16	80.0		19	95.0		
Female	4	20.0		1	5.0		
Diabetes	11	55.0		7	35.0		0.341
Hypertension	11	55.0		10	50.0		1.000
COPD	1	5.0		1	5.0		1.000
Hyperlipidemia	9	45.0		9	45.0		1.000
ESRD	2	10.0		2	10.0		1.000
Cigarette smoking	11	55.0		10	50.0		1.000

SD: Standard deviation; COPD: Chronic obstructive pulmonary disease; ESRD: End stage renal disease.

group. In such case, the expected value for the power of the test was found to be approximately 81.31%.

Statistical analysis was carried out using SPSS for Windows version 15.0 software program (SPSS Inc., Chicago, IL, USA). The demographic data were expressed in mean ± standard deviation. The Mann-Whitney U test and Spearman's correlation analysis were performed. A *p* value of <0.05 was considered statistically significant.

RESULTS

The baseline and demographic characteristics of the patients are shown in Table 1.

The bleeding status was compared under four categories between two groups, as described above. The first, second, and third-degree bleeding were found to be 50%, 30%, and 20% in group 1 respectively. In group 2, the patients with no bleeding, first, second, and third-degree bleeding were found to be 5%, 10%, 25%, and 60%, respectively.

Using the Pearson's chi-square test, the patients with no bleeding were combined with the patients with first-degree bleeding in a single category and the patients were re-examined under three categories (Table 2). In group 1, less severe bleeding was seen, indicating a statistical significance (Fisher's exact test=7,860 and p=0.020) (Figure 1).

The mean width of the injury zone was 0.335 mm and 0.730 mm in group 1 and group 2, respectively (Figure 2). In group 1, the width of the injury zone was significantly lower (Student's t test=4.902 and p=0.000) (Table 3). Desquamation was also seen in the collagen tissue due to collateral thermal injury in the MTK stained ITA samples harvested with electrocautery (Figure 3).

Table 2
Bleeding scores of patients

	Bleeding				
	0 to 1	2	3	*Total*	*p*
Group 1					
Number	10	6	4	20	0.020
Percentage	50.0	30.0	20.0	100.0	
Group 2					
Number	3	5	12	20	
Percentage	15.0	25.0	60.0	100.0	
Total					
Number	13	11	16	40	
Percentage	32.5	27.5	40.0	100.0	

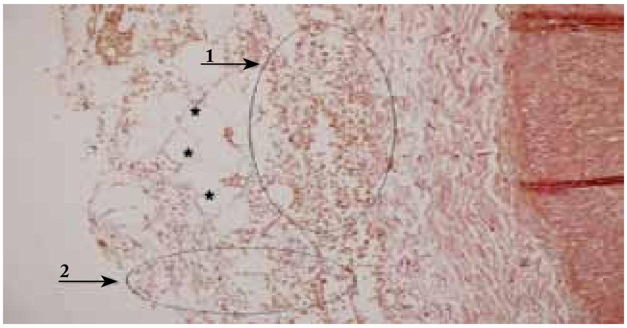

Figure 1. Normal fat cells (★), perivascular free bleeding (1) and minimal thermal injury (2) on the internal thoracic artery wall harvested with the PlasmaBlade™ (stained with elastic van Gieson, magnification x 20).

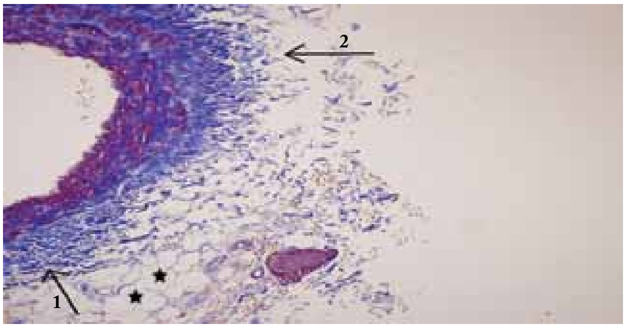

Figure 2. Regular collagen (1) and normal fat cell (★) and significant collagen disintegration (2) induced by thermal injury harvested with conventional electrocautery (stained with Masson's trichrome, magnification x 20).

No endothelial injury was observed in 95% (n=19) of the patients in group 1 and in 60% of the patients (n=12) in group 2 (p=0.020). In both groups, there was no second or third-degree endothelial injury (Table 4). Collateral heat did not cause damage to the collagen tissue in MTK stained ITA samples harvested with the PlasmaBlade™ (Figure 4).

When the congestion scores were reviewed, first-degree congestion was found in 45%, second-degree congestion in 50%, and third-degree in 5% of the patients in group 1, while these were found to be 20%, 65%, and 15% in group 2, respectively. The congestion scores of both groups are presented in Table 5.

The congestion was examined under three categories. Using the Fisher chi-square, the categories were combined to have two categories. However, there was no statistically significant difference in the congestion scores between the groups (p=0.605).

DISCUSSION

Since CABG was first brought into daily practice, several attempts have been made to develop an ideal graft. However, the superiority of the arterial grafts into the venous grafts was proven: the ITA was introduced in 1960s, and since then, it has been the optimal conduit of choice.[2,4,6,14-16] The ITA has higher long-term patency rates, compared to other grafts.[13-15] While the typical atherosclerotic changes and intimal hyperplasia can develop faster in the venous grafts, they are seen much rarely and later with the ITA grafts.[17-21]

Currently, one of the most commonly used techniques in the ITA harvesting is pedicled preparation of the conduit with the surrounding soft tissue, satellite veins, and endothoracic fascia.[2-4,14] This method facilitates harvesting and reduces the possibility of vascular injury.[4] In addition, sustainability of venous and lymphatic drainage ensures the protection of vasa vasorum and continued activity of the conduit.[4,5] Since the very first cases for CABG, it has been prepared using electrocautery.[22] The main goal of using electrosurgery is to ensure a clean and clear incision and coagulation with minimum collateral heat injury.[23,24] The PlasmaBlade™ tissue dissection devices are introduced as novel surgical devices with pulsed-plasma technology to avoid adverse effects of conventional electrocautery.[23,24] It has been developed to induce minimal thermal damage during the tissue dissection and coagulation and the device is called as PEAK® Surgery System together with PULSAR® Generator.[23-25] Most electrosurgical cutting tools use

Table 3
The width of injury zone of patients

	Number	Mean±SD (mm)	Mean±SE	*p*
Group 1	20	0.3350±0.25603	0.05725	0.000
Group 2	20	0.7300±0.25361	0.05671	

SD: Standard deviation; SE: Standard error.

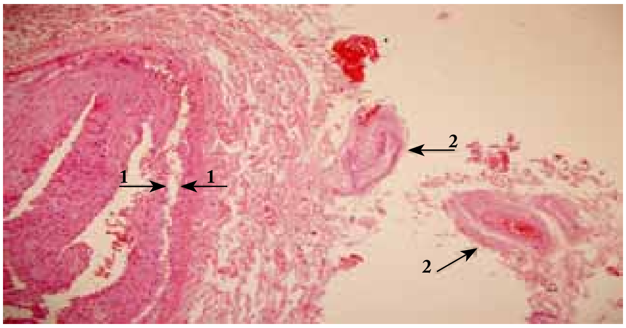

Figure 3. Disintegration of the internal thoracic artery wall (1) and cautery artefacts in small arterioles (2) induced by thermal injury harvested with conventional electrocautery (stained with hematoxylin-eosin, magnification x 10).

continuous radio-frequency (RF) waveforms which thermally vaporize the soft tissue through heating and via an electric arc.[23-25] This results in cutting and coagulation which leaves a wide zone of collateral thermal tissue damage. As the PlasmaBlade™ device receives RF energy in short pulses via a highly insulated cutting electrode, it has an ability to cut at a much lower mean temperature than conventional electrosurgery.[4]

Furthermore, the basic operating principle of this system is that it creates a vapor cloud with the device end contacting with the tissue. The ionization of the water molecules in the vapor cloud creates a specific environment for the dissection. It has been shown that the dissection is performed at a lower temperature (approximately 45 °C) with a lower power, a lower voltage, and a lower current due to the ionization of the water molecules.[23,24] The mean temperature for the conventional cautery is 250 to 350 °C.[23,24] Unlike conventional electrocautery systems, this device does not provide a fixed voltage. Its pulsed-voltage values ranging between +300 and -100 within nanoseconds ensure maximum ionization of the water molecules. As the device end is covered with a glass-based silicon agent, the active region becomes narrow and only the crescent-shaped region which is approximately 0.5 mm thick at the tip is active.[7-11] As the impedance of the tissue decreases within this specifically created environment, less tissue necrosis and thermal damage occur and such a dissection is obtained closer to that performed with a scalpel.[23-25]

A variety of preclinical and clinical studies were carried out in different surgical zones while and after developing the peak surgery system.[23] The studies were initially started with *in vivo* and *ex vivo* preclinical testing on animals and, then, clinical studies were performed.[23] It has been shown through these studies that such a dissection which has a scalpel precision and causes hardly any thermal damages at lower power levels can be performed using the PEAK surgery system and that the system has a hemostasis capability equal to the conventional electrocautery at higher power levels.[23]

No matter how much lower the power is kept in conventional electrocautery during ITA harvesting, the resulting collateral heat may cause damage to both the surrounding tissue and the ITA itself. The traction induced by the perivascular hematoma and electrocautery burn creates a local turbulent flow in the artery. Such turbulent flow may accelerate atherosclerosis due to the endothelial damage as previously reported in the literature and pose an adverse effect on the graft patency.[5] In our study, severe bleeding areas in the perivascular tissue were found significantly higher in the electrocautery group.

Table 4
The extent of endothelial damage of patients

	Endothelial damage			
	0	1	*Total*	*p*
Group 1				
Number	19	1	20	
Percentage	95.0	5.0	100.0	
Group 2				
Number	12	8	20	0.020
Percentage	60.0	40.0	100.0	
Total				
Number	31	9	40	
Percentage	77.5	22.5	100.0	

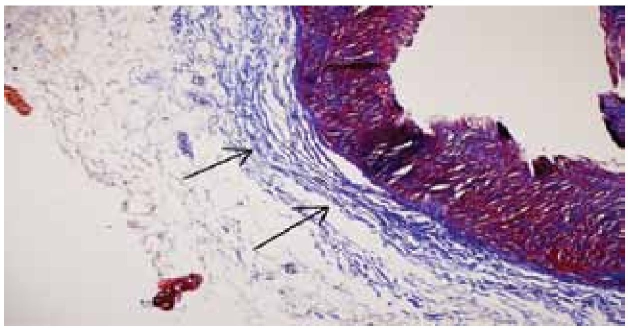

Figure 4. Normal collagen in the internal thoracic artery wall not affected by thermal injury harvested with the PlasmaBlade™ (stained with Masson's trichrome, magnification x 20).

Table 5
Congestion scores of patients

	Congestion				
	1	2	3	*Total*	*p*
Group 1					
Number	9	10	1	20	0.605
Percentage	45.0	50.0	5.0	100.0	
Group 2					
Number	4	13	3	20	
Percentage	20.0	65.0	15.0	100.0	
Total					
Number	13	23	4	40	
Percentage	32.5	57.5	10.0	100.0	

Therefore, we believe that less perivascular bleeding in the pedicle with the PlasmaBlade™ system may reduce the turbulent flow and increase the patency rates.

It has been shown that an intact elastic lamina following the ITA harvesting may prevent atherosclerosis. In our study, the width of the injury zone was found to be significantly lower in the patients treated with the PlasmaBlade™ rather than electrocautery. Thus, it suggests that the PlasmaBlade™ may reduce collateral thermal injuries, and accordingly, increase the graft patency rates.

In another study, Lehtola et al.[26] demonstrated that an endothelial injury and mural thrombosis developed, when the tip of the electrocautery contacted with the ITA wall or the hemostatic metallic clips, which might be a reason for early and late graft failures. In this study, histopathological examination of the electrocautery group revealed thermal damage-induced extensive cautery artefacts in the arterioles of the ITA.

Several preclinical studies have shown that the PlasmaBlade™ requires less than half of the energy produced in the conventional electrocautery devices to achieve similar dissection and coagulation results due to the advance level insulation of its electrode configuration, and its pulsed electric wave forms.[23] This ensures that the temperature during the procedure is less than half of the temperature of the conventional devices, thereby, providing a decrease in the heat transfer by more than a half and a decrease by 50 to 90% in the depth of the thermal injury of the surrounding tissues.[23] Similarly, in our study, the width of the injury zone and severe perivascular bleeding were significantly lower in the PlasmaBlade™ group than the conventional electrocautery group.

Moreover, postoperative sensorial abnormalities on the thoracic wall (i.e. hypoesthesia, hyperalgesia, and allodynia) are associated with the utilization of electrocautery, which may adversely affect the wound healing.[27] It is well-known that the surgical smoke impairs the image quality and the cautery smoke increases the risk of cancer.[28] In addition, the requirement for the cautery tip to be frequently cleaned may be challenging; however, more importantly, burn injuries have been reported in case of improper grounding.[28] In the literature, the advantages of the PlasmaBlade™ have been published.[23] Nonetheless, the ability of the PlasmaBlade™ to provide surgical hemostasis and its effects on postoperative bleeding and blood product utilization should be further evaluated in clinical studies. The major concern of bilateral ITA harvesting is the sternal wound infections, particularly in diabetic patients. Therefore, it should also be investigated whether the Plasmablade™ would make a difference in wound infections.

In conclusion, our study results suggest that the PlasmaBlade™ is safer and more effective in preserving the integrity of the intima and pedicle of the internal thoracic artery than electrocautery for internal thoracic artery harvesting in coronary artery bypass grafting. No matter how much easier electrocautery makes internal thoracic artery harvesting, therefore, novel technologies such as PlasmaBlade™ are needed to be developed to minimize side effects. A well-preserved endothelial function may provide higher graft patency rates.

Declaration of conflicting interests

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