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Microvascular anastomosis using modified micro-stents: A pilot in vivo study

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ABSTRACT

Introduction: Microvascular sutured anastomosis remains the gold standard in microvascular flap surgery but is technically challenging, time-consuming, and sometimes unreliable. The goal of our study has been to develop a microvascular stenting system that can be used for microvascular anastomosis, even without the use of a microscope.
Materials and methods: Custom-made stainless-steel stents were used to re-establish vessel continuity after the severance of the abdominal aortic vessel in nine rats. At 30 min after re-opening the blood flow, Doppler flowmetry and indocyanine green (ICG) angiography were used to assess vessel patency, and vessels were inspected microscopically for signs of thrombosis.
Results: Eight of the nine animals survived the procedure. In one case, the abdominal aorta was torn during balloon dilation of the stent. Four out of the nine stent anastomoses showed an excellent fit. In the remaining four cases, a collagen membrane and fibrin glue were successfully used to stop vascular leakage. However, these additional steps might have had a negative impact on vessel patency, and thrombus formation impaired blood flow completely in one case.
Conclusion: Microvascular stent anastomosis is feasible and might in some cases be superior to standard sutured anastomosis. However, a number of technical difficulties remain to be addressed, and long-term results are not yet available.
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1. Introduction

Microvascular techniques have become the basis for many surgical procedures developed over the past few decades. Although numerous alternative techniques have previously been proposed, interrupted sutures remain the leading technique for microvascular anastomosis. However, this technique is time-consuming and requires microsurgical experience and fundamental training. In particular, small-caliber vessels (diameter <1–2 mm) are often technically challenging, thereby increasing the risk of microvascular failure.

To simplify and to provide more patency and reliability for microvascular anastomosis, various devices have been used in the past. Today, the mainly used non-hand-sewing technique is a coupler-pin system. Although various authors have shown the feasibility of using such a device with arteries, its major use is for venous anastomosis (Grewal et al., 2012). A reliable device for arterial anastomosis is lacking.

To provide an option of microvascular treatment even without the need for profound microvascular skills, the aim of the present study has been to evaluate the use and reliability of a stenting device developed for sutureless arterial microvascular anastomosis. Its application should be possible without the use of the microscope and should be time-saving, easy to perform, and give good results with close anastomoses and tensile strength in comparison with anastomoses involving interrupted sutures.

2. Material and methods

The study was performed according to current German regulations and guidelines for animal welfare and to the international

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principles of laboratory animal care. Nine Wistar rats each weighing between 200 and 300 g were used. General anesthesia was administered with an intraperitoneal injection of ketamine 10% (1 ml/kg weight of body) and xylazine 2% (0.25 ml/kg weight of body) supplemented by quarter-doses when needed. Water and food were given ad libitum. For anticoagulative treatment of rats before stent implantation, clopidogrel (1.5 mg/animal) and acetylsalicylic acid (7.5 mg/animal) were orally administered daily.

2.1. Surgical technique

After the induction of anesthesia, the abdomen and groin were shaved and prepared with an ethanol-propanol solution. Laser Doppler flowmetry was performed at the lower right limb before operation. The rat was fixed in a supine position. A median abdominal skin incision was made, the abdominal space was opened, and the aorta was exposed. The aorta was dissected at the supra- and infrarenal area including its bifurcation with both common iliac arteries. Temporary vessel clips were placed at the suprarenal part of the aorta and one clip each at the common iliac arteries to interrupt blood flow. Afterwards, the aorta was cut in the middle of the dissected area. Insertion of the balloon catheter with the crimped stent was performed at the aortic bifurcation after its incision. The catheter was inserted, and the dissected and severed proximal and distal aortic stumps were approximated with the help of a micro forceps. The ends of the approximated vessel-ends were held stably and closely adapted, while the balloon was gently inflated until a visible expansion of the vessel was noticeable (Fig. 1a–c). After deflation of the balloon, the catheter was removed, and the incision at the aortic bifurcation was closed by two interrupted sutures. All stent anastomoses were investigated under a light microscope (OPMI® Pentero®, Carl Zeiss AG, Oberkochen, Germany) for obvious leakages and sealed with a membrane (BioGide®, Geistlich Pharma AG, CH-6110 Wolhusen) as a cuff. The temporary clips were removed, blood flow was re-established, and after 30 min, laser Doppler flowmetry was performed at the lower right limb. Subsequently, the rats were killed by lethal barbiturate injection and bleeding, the aorta was removed, and the intraluminal site was inspected for any signs of thrombosis under a microscope.

2.2. Stent

The stent used was made of stainless-steel and had a length of 8 mm and an unexpanded diameter of 0.85 mm; the latter could be expanded to 2 mm after vessel insertion (Optiray Medizintechnik GmbH, Germany). The stent was crimped on a catheter with a balloon of 10 mm in length. The balloon could be expanded up to 2 mm, which correlated with that of the stent.

2.3. Measurements

To determine the reliability of the procedure, vessel perfusion, vascular damage, and thromboembolism were measured clinically. Laser Doppler flowmetry was performed with an O2C device (LEA Medizintechnik GmbH, Germany). The parameters blood oxygen level, hemoglobin level, blood flow, and blood velocity were acquired. The perfusion and patency of the stented abdominal aorta was assessed by indocyanine-green (ICG) angiography (Mucke et al., 2012; Mücke et al., 2010; Raabe et al., 2003).

2.4. Statistical analysis

The data (blood oxygen level, hemoglobin level, blood flow, and blood velocity) were analyzed with the “Statistical Package for the Social Sciences” (SPSS for Macintosh, release 20.0, 2011, SPSS Inc.). For descriptive statistics, the quantitative variables mean and median (range) were computed. The Wilcoxon signed test for nonparametric dependent variables was used to compare differences between parameters. Differences were considered to be statistically significant for a two-sided p-value of less than 0.05.

3. Results

Eight out of nine animals survived the procedure (89%). One rat died during the preparation. In one rat, the aorta ruptured during

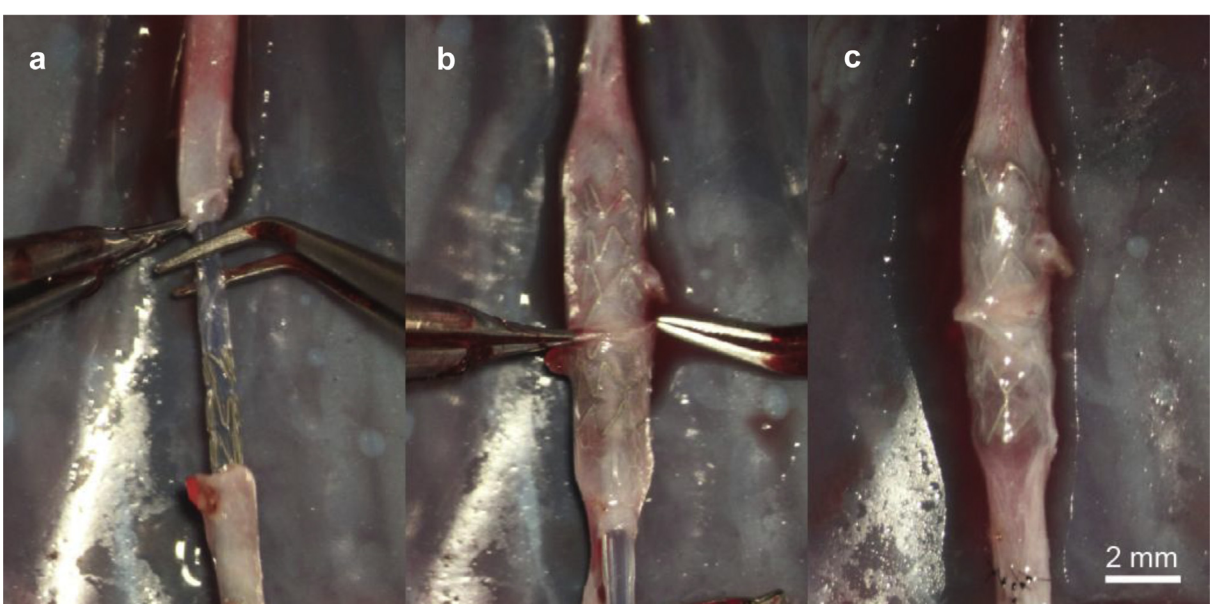

Fig. 1. Surgical procedure for stent anastomosis. (a) Insertion of a catheter containing the crimped stent from the periphery; (b) Approximation of vessel stumps and balloon dilation of the stent; (c) Successful stent anastomosis after the suturing of the access site at the aortic bifurcation (lower border of the figure) and the re-establishing of the blood flow with only minor leakage.

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