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Healing of two microarterial anastomoses with diameter mismatch

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ABSTRACT

Background: The use of fascial perforating vessels as recipients for microvascular composite tissue autotransplants has led to vessel diameter discrepancy becoming an increasingly common finding. Little evidence, however, is available to direct the choice of anastomotic technique where a discrepancy exists. We have been studying two methods of anastomosing arteries where a small-to-large discrepancy exists—a 45° section of the smaller vessel, and invaginating the smaller vessel inside the larger. As part of this work, this study examines intimal hyperplasia and healing of the two methods.

Materials and methods: A previously described paired Wistar rat femoral axis model was used. Anastomoses were performed, one on each side, and specimens were harvested in groups at 24 h, 1 wk, 6 wk, and 8 mo. Inflammation, necrosis, and fibrosis in each layer of the vessel wall and intimal hyperplasia were each scored by an assessor blinded to the group and anastomotic technique.

Results: Significant differences in healing were found. The invagination technique induced less inflammation, and caused less endothelial and medial necrosis than the oblique cut end-to-end method. Intimal hyperplasia was most pronounced at 6 wk, but no evidence of a difference in the severity of intimal hyperplasia between the two methods was found.

Conclusions: The invaginating anastomosis causes less inflammation and less vessel wall necrosis than the oblique end-to-end method in this model. This finding, alongside results from previous work, suggests that this is the better method to deal with a small-to-large microarterial diameter discrepancy in the range 1:1.5 to 1:2.5.

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1. Introduction

Microvascular autotransplantation of tissues and tissue composites is used in reconstruction after trauma or surgical resection of tumors. Developments in the last 15 years have included the adoption of the 'Perforator Principle'—the harvesting of tissues for transplantation based solely on musculocutaneous or septocutaneous perforating vessels, rather

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than using a muscle 'carrier,' in an attempt to reduce donor site morbidity. This principle has been extended more recently also to recipient vessels, for example, using the internal mammary artery intercostal perforators for supply in microvascular breast reconstruction [1–4].

Even without the use of perforators as recipient vessels, diameter discrepancy is commonly found, a recent retrospective observational study in a broad microsurgical practice reporting mismatch in 33% of 150 consecutive arterial and 50% of venous anastomoses. Mismatch in this study was defined as a vessel diameter ratio of 1:1.5 or 1.5:1 or greater [5]. Good experimental evidence exists to suggest that patency rates decrease with increasing mismatch, although the vessel diameter ratio beyond which patency is significantly jeopardized remains undefined [6–8]. Many methods of constructing an anastomosis between vessels of dissimilar diameters are described, but little evidence is available to direct the choice of anastomotic technique in this situation [9–11].

We have been conducting *in silico* [12] and *in vivo* [13] research into two techniques described in the management of a small-to-large arterial diameter mismatch. The techniques under study are a 45° oblique section of the smaller vessel [14], and invaginating the smaller vessel inside the larger [13,15]. *In silico* modeling reported in this journal suggests that areas of complex flow separation exist through both constructs, but that each method produces wall shear stresses of similar magnitudes [12]. No early patency rate difference between the techniques was found in an animal model, although the invagination was found to be faster and technically simpler to perform, an important consideration in the anastomosis of very small vessels [13,16].

In contrast to the end-to-end anastomosis of arteries of an equal diameter, temporal and spatial shear stress gradients encountered when anastomosing vessels of unequal diameter predispose them to alterations in healing, and in particular to the formation of intimal hyperplasia [17–19]. Anastomotic intimal hyperplasia, arising from shear stress abnormalities and from compliance mismatch, has been implicated in late prosthetic and autologous vein graft failure [19,20]. The similar wall shear stress ranges found in the *in silico* study of the two techniques under scrutiny might predict similar degrees of intimal hyperplasia where a size discrepancy exists. A study was therefore designed to quantify intimal hyperplasia and to compare healing of the two techniques in a small-to-large vessel model over the long term.

2. Methods

The following null hypotheses were formed:

"In the anastomosis of arteries of unequal diameter, where a small-to-large diameter ratio of between 1:1.5 and 1:2.5 exists, there is no difference in

1. healing; or

2. intimal hyperplasia, between an invaginating anastomosis and an oblique end-to-end anastomosis in a rodent model."

A previously described animal model was used to create the diameter mismatch [15,16]. In short, a paired, small-to-large diameter ratio of between 1:1.5 and 1:2.5 is created in the femoral axes of outbred Wistar (HsdOla:WI or HsdHan:WIST [Harlan UK Ltd, Bicester, Oxfordshire, UK]) strain rats. All axial blood flow is directed into the superficial caudal epigastric artery (SCEA), which is then anastomosed, end-to-end, to the distal femoral artery (FA) to produce the mismatch (Fig. 1). Use of this model avoids the compliance mismatch inherent in the use of interposition vein grafts, and facilitates a paired study design.

Four time points were arbitrarily selected for study: 24 h, 1 wk, 6 wk, and 8 mo. There was no information on which to base a power calculation and so eight animals per group were arbitrarily deemed suitable. Specimens studied at the 6-wk and 8-mo time points were harvested from consecutive animals used as part of a study into anastomotic patency [13]. Animals included in the 24-h and 1-wk groups were in addition to these animals. Ethical approval for this study was gained from the Animal Ethics Committee of the University of Cape Town. Three further 24-h specimen pairs and eight additional 1-wk specimen pairs were taken from animals used in an as-yet unpublished flow study. Ethical approval and licensing were not required for the harvest of these specimens because the tissues were cadaveric in origin. The inclusion of these additional 22 specimens gave 84 paired specimens from 42 animals.

2.1. Animals

Outbred male Wistar strain rats were used in both studies. Only male animals were used for ease of housing. Animals used in the patency study were obtained from the breeding colony of the Central Research Facility, University of Stellenbosch. This colony was established in 2001 from HsdOla:WI rats, and maintained as an outbred colony. Those used in the flow study were HsdHan:WIST rats (Harlan UK Ltd). All animals were in the region of 350–550 g in body weight. Animal care in the patency experiment was practiced according to University of

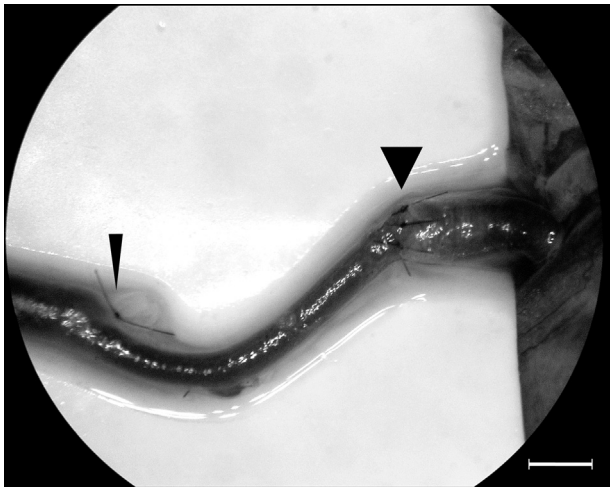

Fig. 1 – An oblique end-to-end anastomosis between the SCEA and the distal FA in the Wistar rat model used in this study. Flow is from left to right. Scale bar = 1 mm. Narrow arrowhead = tie around the FA immediately distal to the origin of the SCEA. Wide arrowhead = anastomosis. Reprinted from Rickard et al. [16]

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