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The position of 'shunt restriction' along an arterialized vein affects venous congestion and flap perfusion of an arterialized venous flap☆

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Summary Restriction of arteriovenous (AV) shunting has been shown to enhance peripheral perfusion and also reduce venous congestion of an arterialized venous flap. Thus, this study is designed to investigate the effect of 'shunt-restriction' location on venous congestion and flap perfusion in a 'shunt-restricted' arterialized venous flap (AVF).
Methods: Abdominal flaps based on the thoracoepigastric vessels of Sprague-Dawley rats were raised. The inferior epigastric vein was repaired to the femoral artery in order to create an AVF. The superior epigastric vein was preserved for drainage. Microcirculation and laser Doppler flowmetry results were compared between AVFs with 'shunt restriction' at a proximal third (SR-proximal) distance and 'shunt restriction' at a distal third (SR-distal) distance.
Results: Bidirectional sluggish flow was detected at the proximal part of venous flaps in both groups. Unidirectional normal flow was observed in more capillaries of the distal flaps in the SR-proximal group. In the middle of the flaps, blood flow was sluggish and intermittent in the veins and was absent in most capillaries of the SR-distal group. The flow was prompt and unidirectional in more capillaries of the SR-proximal group. Using laser Doppler flowmetry, the average perfusion of the whole SR-proximal flaps was found to be higher

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than that of SR-distal flaps ($p = 0.017$). The average flux at the middle and distal portions of the SR-proximal group was significantly higher than those of the SR-distal group ($p = 0.049$).
Conclusion: 'Shunt restriction' at the proximal third of the AV shunt resulted in enhanced perfusion and reduced venous congestion in an AVF.

Introduction

A small arterialized venous flap (AVF) is an ideal flap for the reconstruction of hands and fingers. The pedicle diameter, thickness and pliability of a venous flap harvested from the distal forearm matches that of the recipient site well. However, the unpredictable peripheral perfusion and inevitable venous congestion resulting in flap failure limit its widespread use.

Several studies in the literature attempt to solve this issue, but none are satisfactory. In their retrospective study, Woo et al. recommended using a 'through- and along-valve' pattern of arterialization venous flap for the small defects.[1] In a perfusion study of cadaveric AVFs, Moshammer et al. demonstrated that the peripheral perfusion of these flaps can be enhanced by arterialization against the venous valves.[2] However, partial- and full-thickness losses were not preventable when used clinically.[1,3] A possible explanation of this can be derived from Poiseuille's law, which states that pressure loss is proportional to the length of the vessel. When the volume of inflow and outflow is balanced, and the radius of the afferent and efferent veins is the same, the pressure loss through a short flow-through vein of a small venous flap will be minimal. The intravascular pressure within the arterialized veins will not allow for adequate venous return. Venous congestion may resolve in 7—14 days through neovascularization during the wound healing phase.[4,5] However, the fibrotic change that follows secondary healing in partial flap loss is undesirable in a flap that is applied to the hand and fingers.

In order to enhance peripheral perfusion and reduce venous congestion of an AVF, we previously demonstrated the success of a novel technique known as the 'shunt restriction' of AVFs.[6,7] In this technique, the venous flap is first arterialized along the direction of the valves. A haemoclip is then applied at a location between the arterialized vein and drainage vein, that is, 'shunt restriction'. Arterial flow is hence redirected and perfusion is rerouted through the venous flap. Due to 'shunt restriction', the arterial blood does not flow directly into the draining veins through the venous network, thus creating a pressure gradient that promotes venous outflow (Figure 1).

In our previous studies, we categorized potential anatomical variants of venous network patterns in AVFs and implemented 'shunt restriction' to prevent arteriovenous (AV) shunting.[6,7] The postoperative appearance of 'shunt-restricted' venous flaps is similar to regular arterial flaps and can be monitored without confusion. In our series, the worst outcome was partial loss with epidermolysis of the skin flap. We found that this was more likely to occur in I-pattern-type (a single run-through vessel) venous flaps. Interestingly, in I-pattern venous flaps, we applied 'shunt restriction' at the midpoint of the vessel within the flap. In such cases, mild to moderate venous congestion was observed at the afferent part of the flap (closer to the arterialized vein).

In order to further improve our technique, we proposed the hypothesis that if the 'shunt restriction' is placed closer to the afferent side of the arterialized vein, venous congestion could be reduced while maintaining adequate flap perfusion at the same time. Thus, this study was performed using Sprague-Dawley rats in which the arterial input to venous flow-through flaps was deliberately restricted at various locations either close to the point of inflow or venous outflow. This allowed us to evaluate the effect of various locations of 'shunt restriction' on the development of venous congestion and flap perfusion in AVFs. Laser Doppler flowmetry and microcirculation observation were performed to evaluate changes in perfusion and microcirculation, respectively, when different 'shunt-restriction' locations were applied to a venous flap.

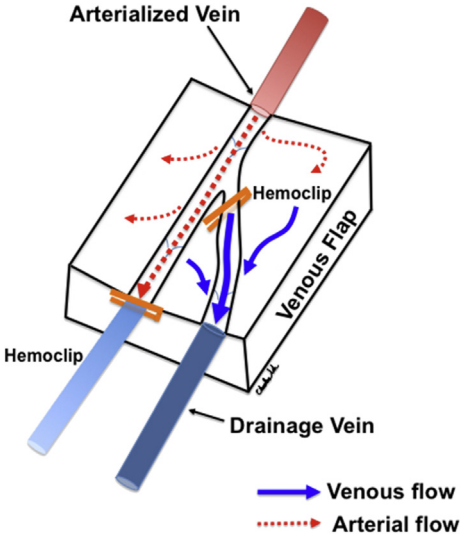

Figure 1 Diagram of arterial and venous flows within a 'shunt-restricted' arterialized venous flap.