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Microvascular assessment of fascio-cutaneous flaps by ultrasound: A large animal study

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Objectives: Blood perfusion quality of a flap is the main prognostic factor for success. Microvascular evaluation remains mostly inaccessible. We aimed to evaluate the microflow imaging mode, MV-Flow, in assessing flap microvascularization in a pig model of the fascio-cutaneous flap.

Methods: On five pigs, bilateral saphenous fascio-cutaneous flaps were procured on the superficial femoral vessels. A conventional ultrasound evaluation in pulsed Doppler and color Doppler was conducted on the ten flaps allowing for the calculation of the saphenous artery flow rate. The MV-Flow mode was then applied: for qualitative analysis, with identification of saphenous artery collaterals; then quantitative, with repeated measurements of the Vascularity Index (VI), percentage of pixels where flow is detected relative to the total ultrasound view area. The measurements were then repeated after increasing arterial flow by clamping the distal femoral artery.

Results: The MV-Flow mode allowed a better follow-up of the saphenous artery's collaterals and detected microflows not seen with the color Doppler. The VI was correlated to the saphenous artery flow rate (Spearman rho of 0.64; $p = 0.002$) and allowed to monitor the flap perfusion variations.

Conclusion: Ultrasound imaging of microvascularization by MV-Flow mode and its quantification by VI provides valuable information in evaluating the microvascularization of flaps.

1 Introduction

Fascio-cutaneous flaps have become the gold-standard technique for complex defect reconstruction (Paro et al., 2016). By sparing the muscle while providing a vascularized skin paddle, the surgeon can cover defects near or distant from the donor site by performing pedicled or free fascio-cutaneous flaps (Cariou, 1995; Boretto and De Cicco, 2022). Assessment of segmental perfusion of a fascio-cutaneous flap is an important viability factor, although challenging in daily practice. When perfusion failure is suspected during surgery and postoperatively, a prompt assessment is mandatory to consider arterial or venous thrombosis and to allow a possible therapeutic procedure (Liu et al., 2020). Ultrasound imaging is particularly suitable because of its ease of use and ability to evaluate superficial tissue with good image quality. However, conventional Doppler modes only allow a limited assessment of flap perfusion, and most microvascularization remains inaccessible. Nevertheless, access to an evaluation of the microvascular network is a major challenge because the good capacity of the underlying microvascular network is responsible for the good perfusion of the flap. New ultrasonic methods dedicated to slow flow visualization have been recently developed to access the microvascular network, such as MV-Flow (Gettle and Revzin, 2020; Giuffrida et al., 2021). Based on a high frame rate associated with dedicated filters, MV-Flow allows a high sensitivity of flow measurements in small arterioles and venules, giving access to a vascular mapping of tissue (Aghababaglou et al., 2022).

Our objective was to evaluate the MV-Flow mode's ability to assess flap microvascularization in a clinically relevant large animal model by evaluating its potential to detect arteriolar and venular microflows and quantify perfusion changes.

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estimation of the perfusion, which can be segmental, and does not require the registration of the feeding artery, which is sometimes not easily accessible in case of a deep artery or poor image quality. Lastly, this mode does not require a dedicated research device as microvascular flow imaging modes are now included in many ultrasound scanners of most of the companies (Gettle and Revzin, 2020; Aziz et al., 2022). A technology transfer to clinical practice is thus potentially achievable under the condition that such equipment will be widely accessible. Further clinical applications of microvascular flow imaging, such as the early detection of intraoperative perfusion defects, even possible by the surgeon himself, will need to be validated.

5 Limitations

The VI has only been used to quantify highly vascularized organs such as the thyroid (mean values of normal thyroid around 20%) or placenta (mean values of normal placenta around 45%) (Chen et al., 2021; Baek et al., 2022). We present the first evaluation on the skin, much less vascularized, thus facing the challenge of accurate signal measurement without motion artifacts. Since *in vivo* microvascular assessment technologies are limited, this study lacks comparison to a gold standard Imaging method. While no reference values are available to compare our data, we expect that our values will be used as a comparison for future studies. Doppler quantification of the arterial flow rate was performed to overcome this limitation by giving insight into global flap perfusion. Another limitation is that the VI has not been directly compared to visualization in color Doppler. A color Doppler vascularity index has been proposed for organs that are more perfused than the fascio-cutaneous flap, such as the kidney or the thyroid (Chen et al., 2002; Sultan et al., 2015; Zhang et al., 2022). In these cases, the higher blood flow velocities allowed for color mapping and area comparison with conventional Doppler. However, this was not the case for cutaneous and subcutaneous tissues where low blood flow velocities resulted in poor color Doppler visualization. Lastly, VI should be ideally measured in 3D. A perspective is the use of a 3D mode of microvascular imaging currently arising (Zhang et al., 2019; Cai et al., 2021).

6 Conclusion

Ultrasound imaging with MV-Flow and microflow quantification by Vascularity Index provides valuable information in evaluating flap microvascularization.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The animal study was reviewed and approved by Massachusetts General Hospital (Boston, MA, United States) Institutional Animal Care and Use Committee (Protocol 2020N000015).

Author contributions

AL, BU, and GG conceived the study. AL and BU supervised the study. GG and YB collected the data. YB, EC-T, and CG performed the surgery. GG and YB performed the statistical analysis. GG and YB wrote the manuscript. All authors interpreted the data, drafted, and revised the manuscript, and approved the final version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fphys.2022.1063240/full#supplementary-material

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