Journal of Plastic, Reconstructive & Aesthetic Surgery 96 (2024) 196–198

Correspondence and Communications

Correlation between laser Doppler flowmetry metrics and continuous blood pressure in free flap monitoring

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Received 28 June 2024; Accepted 22 July 2024

KEYWORDS
Free flap;
Reconstruction;
Laser Doppler flowmetry;
Flap monitoring

Dear Editor,

The laser Doppler flowmetry (LDF) has been utilised in microsurgical free tissue transfer-based reconstruction as a non-invasive monitoring method where the Doppler shift of a laser source is shined into the flap to measure blood flow velocity, which is then consequently used to estimate tissue perfusion. Several studies have reported successful outcomes with its use.[1] However, LDF has several limitations, such as variations in estimates due to physiological factors, high cost, external artefacts and difficulty in data interpretation.[2]

To address these issues, we propose a method to achieve accurate objectification of human data through the combined use of vital signs data. With recent technological advancements, the importance of automatic collection of basic vital signs such as blood pressure, body temperature, and respiratory rate has been recognised.[3] Furthermore, the usefulness of multimodal sensors, which utilise multiple measurement principles, in flap monitoring has been

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https://doi.org/10.1016/j.bjps.2024.07.059
1748-6815/

Table 1 Patient demographics.

Flap type	Recipient Artery	Recipient Vein	Flap outcomes	Measurement minutes	Perfusion Average (ml/min) [min-max]	BP Average (mmHg) [min-max]
ALT	Fibula	Fibula	TN	487	2.1 [0–7.5]	104 [76-155]
DIEP	TC	EJ	S	711	12.8 [3.4–23.2]	117 [91-144]
RF	F	F	TN	612	2.0 [1.5–2.6]	113 [85-139]
DIEP	S Thy.	CF	S	328	9.5 [8.5–13.3]	112 [98-156]
LD	SG	SG	S	869	3.2 [2.1–6.0]	134 [84–217]
RAMc	S Temp.	S Temp.	S	202	9.2 [6.2–19.1]	145 [90–209]
ALT	S Thy.	IJ	S	1046	5.2 [1.6–9.0]	122 [82-166]
RAMc	S Thy.	CF	S	807	15.0 [4.4–33.7]	127 [105–231]
RAMc	F	F	S	852	4.0 [2.9–5.6]	127 [98-150]
LD	S Temp.	S Temp.	S	922	9.0 [3.5–12.8]	144 [92-187]
ALT	S Temp.	S Temp.	S	811	8.3 [7.4–10.1]	111 [75-152]
ALT	S Temp.	S Temp.	S	829	7.7 [4.9–11.9]	120 [96-151]
LD	S Temp.	S Temp.	S	755	10.6 [5.4–16.8]	114 [92-158]
Fibula	F	F	S	663	12.9 [5.0–32.4]	119 [83–192]
RAMc	S Thy.	EJ	S	748	6.1 [5.1–8.1]	125 [83-175]
LD	S Temp.	S Temp.	S	583	4.0 [3.8–4.9]	128 [99-193]

ALT: Anterolateral Thigh flap, BP: Blood Pressure, CF: Common Facial, DIEP: Deep Inferior Epigastric Perforator flap, EJ: External Jugular, F: Facial, IJ: Internal Jugular, LD: Latissimus Dorsi flap,RF: Radial Forearm flap, RAMc: Rectus Abdominis Musculocutaneous flap, S: Survive, SG: Superior Gluteal, S Temp.: Superficial Temporal, S Thy.: Superior Thyroid, TC: Transverse Cervical, TN: Total Necrosis

reported.[4] At our Japanese centre, we have investigated the relationship between flap LDF data and systemic blood pressure, which resulted in insightful findings.

The study population consisted of patients who underwent free tissue transfer surgery and were admitted to the intensive care unit (ICU) postoperatively. The study was performed with the consent of all patients and ethics committee approval. Free flap blood flow was measured using the Pocket LDF® (JMS, Japan) (Supplement 1). The sensor was mounted without contact with the flap margins and measurements were taken postoperatively until the following morning. Furthermore, continuous blood pressure measurements from a peripheral arterial line catheter were recorded. Patients with flaps placed in the oral cavity and those whose sensors detached during the procedure were excluded. LDF was introduced merely as a research tool, and its data was not utilised by surgeons when assessing the flap. Therefore, improvements in flap salvage rates due to the introduction of LDF were not evaluated.

Supplementary material related to this article can be found online at doi:10.1016/j.bjps.2024.07.059.

A total of 16 patients were included in the study, out of which two (12.5%) were diagnosed with flap ischaemia, and measurements were terminated. Patient demographics are provided in Table 1. We have selected five representative cases of two flap failures and the three oldest control cases to overlay the blood flow (ml/min) with systolic blood pressure (SBP). Corresponding scatter plots are shown in Figure 1. Intuitively, in intact cases, the overlay chart showed the two waveforms overlapping well, and the scatter plots displayed a coherent upward trend, unlike the ischaemic cases. This suggests that blood flow and SBP show a real-time linked trend.

Microvascular blood flow is associated with peripheral arterial resistance.[5] The data from the intact cases in the present study seem to support this. On the other hand, this study encountered several limitations that warrant further discussion. Initially, the relatively small number of ischaemic cases restricted the robustness of statistical analyses that could be conducted. Moreover, the variability in flap types and recipient vessels presented challenges in collecting homogeneous data.

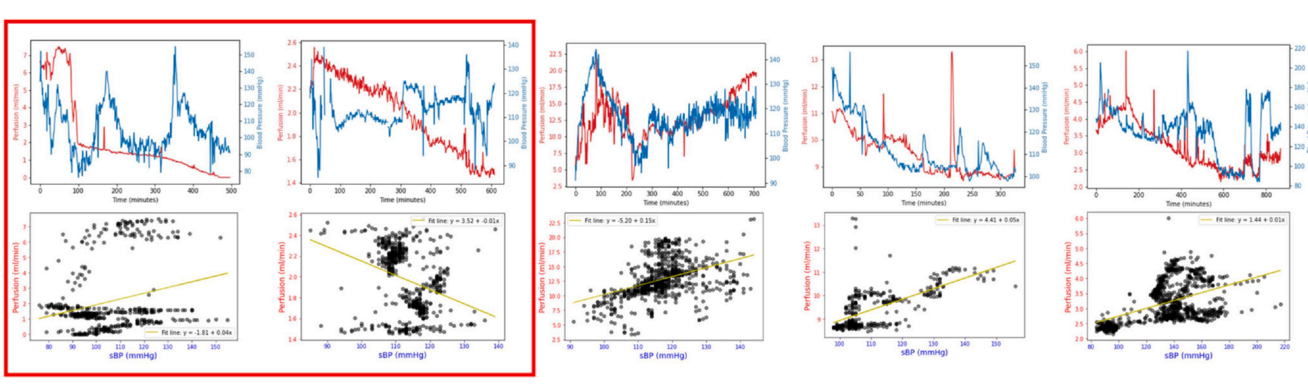

Figure 1 Overlay charts and scatter plots showing the relationship between blood flow and systolic blood pressure in flaps of ischaemic cases (in the red box) and the three oldest records of normal cases.

The application of laser Doppler flowmetry (LDF) proved to be problematic when used for buried flaps or within the oral cavity due to movement-induced artefacts. Furthermore, certain surgical procedures such as breast reconstruction and digital replantation did not require ICU admission, thus precluding the acquisition of continuous blood pressure data. Furthermore, LDF data and blood pressure readings were stored independently, necessitating manual synchronisation of timestamps to analyse the interdependencies, suggesting a need for system integration in future protocols. A zeroing manoeuver in arterial blood pressure measurement using pressure transducers, bending/kinking of peripheral arterial catheters and the administration of drugs that constrict or dilate peripheral arteries are considered as major factors that distort the validity of blood pressure data and its correlation with blood flow.

Graphs generated from the entirety of data collected during the measurement period may have provided initial insights; however, the ultimate goal of real-time anomaly detection demands continuous computational analysis. Advances in machine learning and artificial intelligence (AI) would make this possible. Future studies should focus on evaluating whether LDF data overlayed with vital sign data can facilitate earlier and more accurate detection of anomalies compared to traditional clinical assessments, potentially leading to significant advancements in patient monitoring and outcomes.

Various devices have been developed for free flap monitoring, yet there is still no established gold standard. Particularly for early detection and intervention, devices that allow continuous and automatic measurement are preferable over those that can only be evaluated at the time of medical staff intervention. Previous flap monitoring data analysis for anomaly detection has primarily used threshold setting and comparison with historical data. However, our study suggests that the performance of anomaly detection can be improved by combining it with other vital signs data. With the advancement of machine learning and AI, the importance of medical data is increasingly recognised. Therefore analysing continuous data related to free flaps potentially provides crucial insights for conceiving next-generation monitoring strategies.

Ethics approval

All procedures performed in the study involving human participants were in accordance with the ethical standards of the local research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The present study was approved by The Jikei University School of Medicine Ethics Committee (Application Permit Number; 32-347(10434)).

Funding

No funding was received.

Conflict of interest

Hiroki Kodama, Katsuhiro Ishida, Haruyuki Hirayama, Doruk Orgun, Kazuho Kawashima, Dariush Nikkhah, James May, Panicos Kyriacou and Takeshi Miyawaki declare that they have no conflict of interest.

Acknowledgements

None.

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