

Dynamic Changes on Video-capillaroscopy and Potential Microsurgical Application: Temperature and Skin Surface Readings

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Summary: Video-capillaroscopy is being explored as a potential tool for microsurgical flap monitoring. A detailed examination of the effect of temperature on capillary changes using video-capillaroscopy is yet to be investigated. We analyzed the video-capillaroscopy findings on different skin areas often used for flap harvest at normal body temperatures and at lower temperatures. Skin capillaries at the lateral thigh, anterior forearm, mid-axillary line, abdomen, and fingertips were observed using video-capillaroscopy in 20 healthy Japanese individuals. Further, ImageJ software was used to measure the blood vessel area and blood flow velocity, and comparisons were drawn between normal body temperature and lower body temperature states. All measures of blood vessel area and average blood flow velocity for the different anatomical regions were significantly different before and after cooling ($P < 0.001$). The mean reduction rate of the vessel area was significantly different among anatomic regions ($P < 0.001$). Post-hoc analysis revealed a significant difference in the vessel area reduction rate between anatomic areas ($P < 0.05$); except when comparing the thigh versus finger, the forearm versus abdomen, and the mid-axillary line versus abdomen. The mean blood flow velocity was significantly different among anatomic regions ($P < 0.001$). Post-hoc analysis revealed a significant difference between the thigh and forearm ($P = 0.009$), the forearm and fingertip ($P = 0.001$), and the abdomen and fingertip ($P = 0.004$). Decreasing the skin temperature resulted in a significant vasoconstriction and reduction in capillary flow velocity. It is imperative to keep the monitored area warm during video-capillaroscopy assessment to avoid false diagnosis of vascular occlusion. (*Plast Reconstr Surg Glob Open* 2022;10:e4265; doi: [10.1097/GOX.0000000000004265](https://doi.org/10.1097/GOX.0000000000004265); Published online 14 April 2022.)

INTRODUCTION

Neoteric technologies for flap perfusion monitoring provide ancillary assistance to identify complications in

a well-timed fashion. Nevertheless, limitations regarding the operator-dependent outcomes and the precision of these technologies, as well as the lag to recognize the actual onset of microvascular occlusion, remain a major concern.^{1,2}

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Video-capillaroscopy, a noninvasive microcirculation monitoring modality routinely used to evaluate nail capillary changes in patients with collagen diseases,³ was used in a recent study to evaluate changes in the capillary microcirculation of human flaps with a protocol of artery- and vein-controlled clamping.⁴ We achieved real-time flap monitoring by directly visualizing the flap's skin capillary microcirculation, but the impact of the skin temperature on video-capillaroscopy was not evaluated.⁴ Thus, to evaluate the impact of temperature during video-capillaroscopy monitoring, we analyzed video-capillaroscopy findings on different skin areas often used for flap harvest at normal and lower body temperatures.

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Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

PATIENTS AND METHODS

Study Design

This study was approved by the institutional and maxillofacial review board public of a cooperative institution of Juntendo University (IRB No. 241) and registered at UMIN Clinical Trials Registry (UMIN000041092). This investigation was conducted according to the principles expressed in the Declaration of Helsinki.

We conducted a prospective investigation between 2020 and 2021, in which capillaries of twenty healthy Japanese individuals were evaluated using video-capillaroscopy to analyze the blood vessel area reduction rate and blood flow velocity reduction rate after cooling. We excluded subjects with a diagnosis of vasculopathy and vasculitis.

Study Procedure

Skin capillaries were observed at the anterolateral thigh; between the distal third and proximal two-thirds of the anterior forearm; mid-axillary line, at the level of the nipple; abdomen (periumbilical); and ring fingertip using video-capillaroscopy (GOKO Bscan-Z). (See Video [online], which displays observations of video-capillaroscopy at normal temperature and after cooling in the anterolateral thigh, forearm, mid-axillary line, abdomen, and the fingertip skin.) Ice packs were used for 10 minutes to lower the skin temperature to less than 35°C. Measurements were recorded three minutes before and after cooling; then, they were compared. We evaluated the blood vessel area reduction rate (%) by means of ImageJ software,⁵ which was obtained by dividing the total blood vessel area (pixels) per visual field over the area of the entire visual field (pixels). The blood flow velocity ($\mu\text{m/s}$) was measured using GOKO-VIP software.

Statistical Analysis

The vessel features and rheological parameters were compared with a paired *t* test. One-way analysis of variance and Tukey's honest significant difference test were used to identify significant differences in the blood vessel area reduction rate and blood flow velocity reduction rate among anatomical zones. Jamovi 1.2.27.0 (Jamovi, Australia) was used for statistical analysis. An alpha of less than 0.05 was considered statistically significant.

RESULTS

The protocol was conducted successfully (Table 1). The average age and BMI were 37.5 ± 9.72 years and 22.4 ± 2.45 kg per m^2 . The mean arterial pressure was 89.4 ± 3.1 mm Hg. In accordance with the Fitzpatrick phenotype, 11 patients were type II, five were type III, and four were type IV (Fig. 1).

The average skin temperature before cooling was $(36.4 \pm 0.2)^\circ\text{C}$, and $(34.7 \pm 0.8)^\circ\text{C}$ after cooling (Table 2). The average blood vessel areas before and after cooling

Takeaways

Question: Video-capillaroscopy is being explored as a potential tool for microsurgical flap monitoring. What is the effect of lowering the skin surface temperature in areas often used for flap harvest on video-capillaroscopy evaluation?

Findings: We lowered the skin temperature of the lateral thigh, forearm, mid-axillary line, abdomen, and the fingertip to less than 35°C in 20 healthy Japanese subjects. All measurements of blood vessel area and average blood flow velocity for all the areas were significantly different before and after cooling ($P < 0.001$).

Meaning: It is imperative to keep the monitored area warm during video-capillaroscopy assessment to avoid false diagnosis of vascular occlusion.

were significantly different ($P < 0.00$) for all measurements. The average reduction rate of the vessel area (%) after cooling was 63% for the thigh, 30% for the forearm, 43.3% for the mid-axillary line, 35% for the abdomen, and 65% for fingertips (Fig. 2). The mean reduction rate of the vessel area was significantly different among anatomic regions ($P < 0.001$). Post-hoc analysis revealed a non-significant difference between the thigh and fingertips ($P = 0.983$), the forearm and abdomen ($P = 0.61$), and the mid-axillary line and abdomen ($P = 0.116$). The rest were statistically significant.

The average blood flow velocity before and after cooling were significantly different for all measurements ($P < 0.001$). The average blood flow velocity reduction rate after cooling was 75.7% for the thigh, 55.3% for the forearm, 68.9% for the mid-axillary line, 61.6% for the abdomen, and 79.2% for fingertips. The average blood flow velocity reduction rate after cooling was significantly different among anatomic regions ($P < 0.001$). Post-hoc analysis revealed a significant difference between thigh and forearm ($P = 0.009$), forearm and fingertips ($P = 0.001$), and abdomen and fingertips ($P = 0.004$). (See Video [online].)

Table 1. Demographic Information

Variable	
Patients, n (%)	20 (100%)
Age \pm SD, y (range)	37.5 ± 9.72 (22–55)
Gender	
Men	9 (45%)
Women	11 (55%)
BMI \pm SD, kg/m^2 (range)	22.4 ± 2.45 (18.9–27.4)
Mean arterial pressure	89.4 ± 3.1 (82.7–95)
SBP	117 ± 7.19 (105–131)
DBP	75.4 ± 23.56 (70–81)
Fitzpatrick phenotype	
II, n (%)	11 (55%)
III, n (%)	5 (25%)
IV, n (%)	4 (20%)

SBP, systolic blood pressure; DBP, diastolic blood pressure.

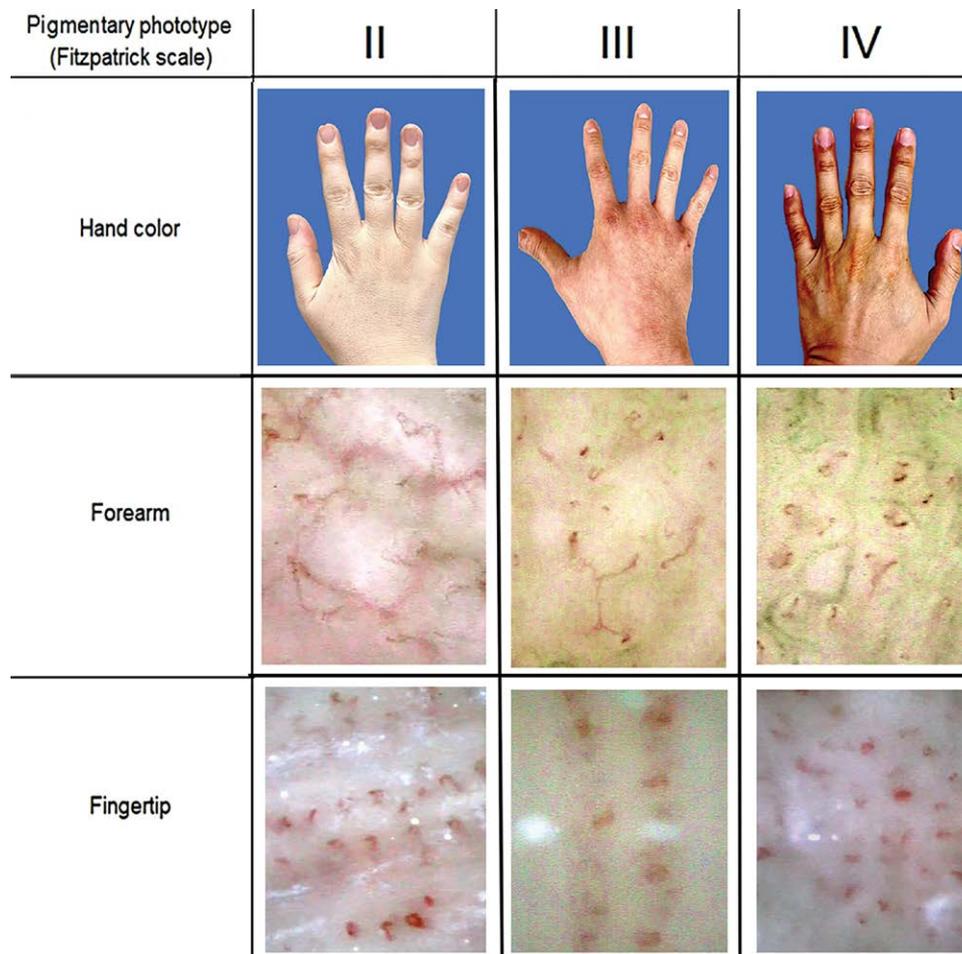


Fig. 1. Different amounts of skin melanin increase the intricacy of video-capillaroscopy recording and analysis.

DISCUSSION

We have successfully demonstrated preliminary results on the reliability of video-capillaroscopy for flap monitoring.⁴ We depicted similar capillary densities (31.4 ± 5.7 number/mm²) and flow velocities (252.7 ± 8.2 $\mu\text{m/s}$) before flap harvest and 2 hours after a successful anastomosis (30.9 ± 6.6 number/mm²; 251.0 ± 19.8 $\mu\text{m/s}$).⁴ Also, with this modality, images generated from a real-time video were useful to differentiate between arterial or venous thrombosis on a microcirculatory level.⁴

To establish guidelines for video-capillaroscopy in flap monitoring, the authors have demonstrated the effect of temperature on capillary flow in this study. According to our results, there is a reduction in blood vessel area and blood flow velocity in all evaluated anatomical regions (lateral thigh, forearm, mid-axillary line, and fingertip) when video-capillaroscopy is used at a lower temperature due to the thermoregulatory-mediated vasoconstriction of vessels.⁶ Certainly, the higher variations were seen when evaluating the thigh and fingertips due to their peripheral disposition.

Table 2. Measurements of Skin Temperature, Blood Vessel Area, and Blood Flow Velocity

	Total	Thigh	Forearm	Mid-axillary Line	Abdominal	Finger
Normal skin temperature \pm SD ($^{\circ}\text{C}$)	36.4 ± 0.208	36.4 ± 0.157	36.3 ± 0.187	36.4 ± 0.201	36.4 ± 0.163	36.1 ± 0.17
Cooling skin temperature \pm SD ($^{\circ}\text{C}$)	34.7 ± 0.772	34.5 ± 0.8	34.5 ± 0.787	34.5 ± 0.797	34.5 ± 0.797	34.5 ± 0.755
<i>P</i> value*	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Normal mean blood vessel area	6.52 ± 1.44	5.66 ± 0.579	7.34 ± 1.53	5.44 ± 0.595	8.42 ± 0.603	5.75 ± 0.502
Cooling mean blood vessel area	3.53 ± 1.66	2.07 ± 0.38	5.09 ± 1.18	3.02 ± 0.494	5.46 ± 0.947	2 ± 0.395
<i>P</i> value*	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blood vessel area reduction rate (%)†	47.2 ± 18	63 ± 8.07	29.9 ± 12.5	43.3 ± 13.7	34.9 ± 11.2	64.9 ± 8.16
Normal blood flow velocity ($\mu\text{m/s}$)	292 ± 116	331 ± 93.3	296 ± 119	363 ± 149	241 ± 58.8	230 ± 88.5
Cooling blood flow velocity ($\mu\text{m/s}$)	80.7 ± 35.2	74.1 ± 10.4	108 ± 45.9	94.6 ± 35.6	85.1 ± 14	41.3 ± 8.21
<i>P</i> value*	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Blood flow velocity reduction rate (%)†	68.2 ± 20.6	75.7 ± 9	55.3 ± 32.7	68.9 ± 17.9	61.6 ± 15.3	79.2 ± 10.4

*Paired *t* test of measurements before and after cooling.

†One-way analysis of variance ($P < 0.001$).

	Thigh	Forearm	Skin on the mid-axillary line	Abdominal skin	Fingertip
Mean temperature	36.4°C	36.3°C	36.4°C	36.4°C	36.1°C
Normal body temperature					
Mean temperature	34.1°C	33.9°C	34.6°C	33.9°C	34.2°C
Cold stimulation					

Fig. 2. Typical video-capillaroscopy observations.

In our previous study, we found a mean blood flow velocity of $18.9 \pm 4.4 \mu\text{m}$ per second and $20.7 \pm 1.2 \mu\text{m}$ per second at 60 seconds after arterial and vein clamping, respectively.⁴ In comparison, we were able to identify blood flow velocities as low as $23.1 \mu\text{m}$ per second after cooling in this study. Therefore, warming the monitored area before using video-capillaroscopy to obtain accurate information of the microcirculatory status is recommended to prevent false interpretations of vascular occlusion, especially during lower and upper extremity reconstruction.

Video-capillaroscopy is a promising flap monitoring modality that can be versatile in identifying impending flap compromise and differentiating the type of vascular occlusion under appropriate circumstances. Limitations of the current study include the limited anatomical areas evaluated with capillaroscopy and the external validity of findings, as patients requiring free flaps are not in optimal health conditions.

CONCLUSIONS

Lowering the skin surface temperature resulted in significant capillary vasoconstriction and decreased capillary blood flow velocity in all anatomical areas. When video-capillaroscopy is used to evaluate perfusion, it is important to keep the spotted topographic area warm as decreasing the temperature of the monitored

area might translate into a false diagnosis of vascular occlusion.

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