Comparison of Laser Doppler Flowmetry and Thermometry in the Postoperative Monitoring of Replantations

Steven E. R. Hovius, MD, PhD, Léon N. A. van Adrichem, MD, PhD, H. D. Mulder, MD, R. van Strik, DSt, J. C. van der Meulen, MD, PhD, Rotterdam, The Netherlands

Reliable postoperative monitoring in microvascular surgery is necessary to improve the success rate of reexplorations following vascular compromise. Surface thermometry is known as an easy and inexpensive objective postoperative monitor and therefore is used by many microsurgeons. Reliability, however, is not satisfactory, and therefore several other instrumental methods have been tested of which laser Doppler flowmetry shows the most promising results. This study compared laser Doppler flowmetry to thermometry in the postoperative monitoring after replantation surgery. In 34 patients, 45 replantations and revascularizations were monitored by laser Doppler flowmetry and thermometry. A reliable alarm value of 10 PU was defined for replantations and revascularizations, with a sensitivity of 93% and a specificity of 94%. Thermometry showed a sensitivity of 84% and a specificity of 86% at 29°C. (J Hand Surg 1995;20A:88–93.)

The most feared complication in microvascular surgery is occlusion of anastomoses. Early recognition of this condition may prevent the loss of replanted or free vascularized tissue, as the blood flow can be restored by reconstructing the vascular anastomoses. It is essential to recognize the vascular compromise early, because the effectiveness of intervention is inversely related to the time that has elapsed between suspicion of vascular compromise and reexploration.[1] Clinical judgment alone is not satisfactory, therefore several methods have been developed to monitor microcirculation or establish the patency of microvascular anastomoses.[2–4]

Postoperative monitoring should be objective, direct, noninvasive, reliable, continuous, easy, and inexpensive. The tissue surface thermometry is known as an easy and inexpensive postoperative monitor and therefore is used by many microsurgeons. Unfortunately, tissue temperature is easily influenced by the surroundings. Nevertheless, several authors have demonstrated enthusiasm for surface temperature measurements as a method of monitoring following microvascular surgery.[5–8] The critical temperature, below which reexploration is indicated, should be 30°C.[9] Leonard and Brennen[10] stated that two thermocouples should be used, one on the revascularized tissue and one on adjacent normal skin. A difference of 2°C between the two should indicate circulatory impairment.

Because thermometry is not always the ideal monitor in microvascular surgery, other methods

From the Department of Plastic and Reconstructive Surgery, University Hospital Dijkzigt and Department of Biostatistics of the University of Rotterdam, Rotterdam, The Netherlands.

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Reprint requests: Dr. S. E. R. Hovius, University Hospital Dijkzigt, Department of Plastic and Reconstructive Surgery, Dr. Molewaterplein 40, 3015 GD Rotterdam, The Netherlands.

have been studied. The most recent reports have been on laser Doppler flowmetry, and promising results were presented, although some predictions were false.[11-17]

Pietila et al.[18] compared laser Doppler flowmetry and thermometry in the postoperative monitoring of replanted rabbit ears and concluded that the laser Doppler flowmeter was more sensitive to changes in capillary blood flow, but the reproducibility of the method was worse than that of thermometry.[18]

Materials and Methods

During the study period, 45 replantations and revascularizations were monitored in 34 patients. The mean age of the patients was 35 years (range, 7–62 years), and the male to female ratio was 32 to 2. The patients were monitored by laser Doppler flowmetry and thermometry for 5 days postoperatively unless a reexploration was necessary. Following reintervention, patients reentered the study for another period of 5 days.

Laser Doppler Flowmetry

The laser Doppler flowmeter (Perimed KB, Järfälla Sweden) has been extensively described previously.[19-23] Values obtained by laser Doppler flowmetry (LDF) are presented in perfusion units (PU).

LDF measurements were taken continuously at the same site, that is, the pulp skin of the distal phalanx. A probe holder was sutured to the skin so that the fiber optic cable was held continuously at a constant distance from the skin surface.

Thermometry

The surface temperature was measured by a thermocouple connected to a thermograph (Y.S.I. 44 TA, Yellow Springs, OH). Temperature is an indirect measurement of skin perfusion, which is influenced by the temperature of the deeper tissues and of the surroundings. The thermocouple was fixed by medical adhesive tape to the dorsal skin of the distal phalanx of the replanted digit (the same finger used for LDF monitoring), as well as a control digit in the same hand skipping, the adjacent digits when possible.

Statistical Analysis

The 5 days of monitoring were split into 240 30-minute periods. Within every 30-minute period the mean value of LDF measurements was obtained as well as a single skin temperature measurement and a difference in temperature between the control and replanted digit. For further analysis of each parameter, the lowest of the thus obtained values per recording was used.

Patients were divided into three groups, according to the clinical course, which was (1) uncomplicated, (2) compromised (e.g., hematoma, compression, vascular kinking), and (3) complicated by an arterial or venous occlusion.

For every parameter the two-tailed Mann-Whitney rank sum test was used to assess differences between the uncomplicated and vascular occlusion group. The Spearman rank correlation test was used to assess the strength of relationships between the different parameters. Analysis of sensitivity and specificity was performed. It was assumed that the 41 uncomplicated cases and the 10 cases with a vascular occlusion were representative for the relevant populations. The rankit score method was used to estimate the distributions of laser Doppler flow measurements within these relevant populations in order to calculate the sensitivity and specificity.

Results

In the 34 patients with 45 replantations or revascularizations, 52 recordings were made (Fig. 1).

All 52 laser Doppler recordings were complete, 4 temperature recordings of the replants were incomplete, and in 3 cases no reliable control temperature was measured.

The results of LDF monitoring are described in Figure 2 and Table 1. The results of thermometry recordings are displayed in Figures 3 and 4 and Table 1.

LDF and temperature were highly correlated (rho $= 0.681$; $p < .0001$), as well as LDF and differential temperature (rho $= 0.622$; $p < .0001$). Also, temperature and differential temperature showed a high correlation (rho $= 0.805$; $p < .0001$). For comparison of LDF and thermometry, sensitivity and specificity curves were made for both monitoring methods for the studied group as well as for the total population (Figs. 5 and 6).

Discussion

The effectiveness of reintervention is inversely related to the time that has elapsed between the suspicion of vascular compromise and reexploration.[1] Kerrigan et al. demonstrated in cutaneous island flaps in pigs that the secondary critical ischemic time for 90% flap survival (4.7 hours) was far less than the primary critical ischemic time (7.0 hours).[24] Therefore, reintervention in clinically failing microvascular procedures should be as early as possible. The decision to reexplore on the basis of clinical judgment alone, even by experienced surgeons, has

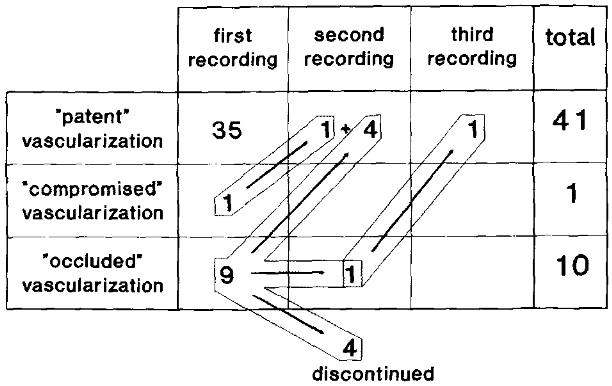

Figure 1. Fifty-two recordings in 34 patients with 45 replantations. Seven reexplorations were performed, and six were monitored postoperatively. No reexploration was performed in three cases. The difference in numbers between the recordings and replants was due to reentry of cases into the study following vascular compromise. During 41 recordings the course was uncomplicated, during, recording compromised (haematoma) and during 10 recordings a vascular occlusion occurred. The compromised replant was successfully reexplored and after removal of the haematoma the replant survived. In 9 replants a vascular occlusion occurred. Three patients were not reexplored; one patient suffered from respiratory problems, which were a contraindication for anaesthesia, and in two patients the vascular reconstruction was made on very small vessels, so that secondary reconstruction was technically impossible. In five patients a reexploration was performed; four reexplorations were successful and in one patient a reocclusion occurred, but a second reexploration saved the replant. One reexplored replantation could not be monitored due to lack of apparatus.

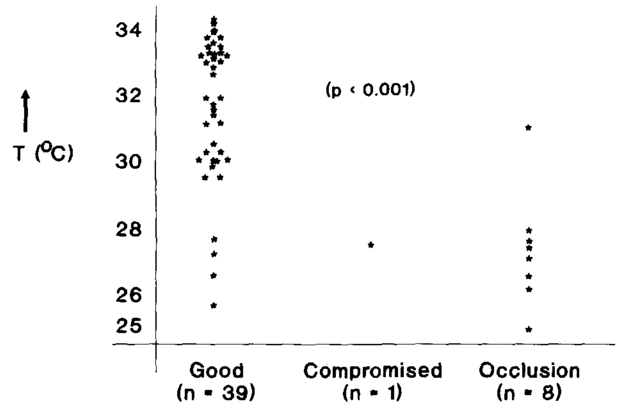

Figure 3. The lowest 30-minute temperature value of every replantation and revascularization registration is shown in this diagram. The good cases ranged from 25.6° to 34.1°C (mean, 31.5°C); in the compromised case the value was 27.5°C, and the vascular occlusion cases ranged from 25.0° to 31.0°C (mean, 27.2°C). The difference between the good cases and vascular occlusion cases was significant ($p < .001$).

proven to result in considerable time loss and a high secondary failure rate of up to 60%. This is especially valid during the night, when most failures tend to occur and experienced staff is not always present.

Thermometry has been used by many microvascular surgeons in postoperative monitoring because it is easy, inexpensive, and objective. False predictions, however, were made by this method, and a more nearly ideal monitor was researched. LDF seemed to be the most promising, although it is a

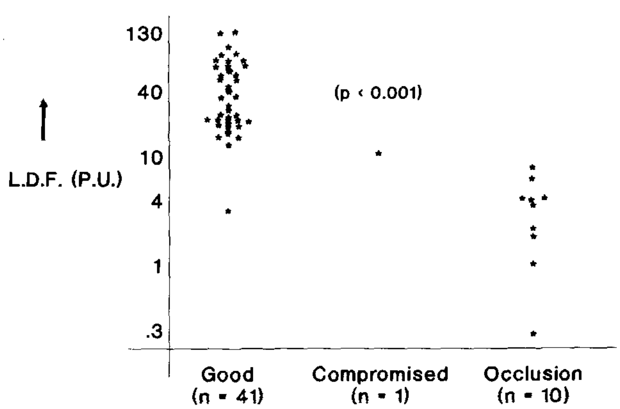

Figure 2. The lowest mean 30-minute LDF value of every replantation and revascularization registration is shown in this diagram on a logarithmic scale. The good cases ranged from 3.3 to 130 PU (mean, 49 PU); in the compromised case the value was 10 PU, and the vascular occlusion cases ranged from .3 to 8.0 PU (mean 3.7 PU). The difference between the good cases and vascular occlusion cases was significant ($p < .001$).

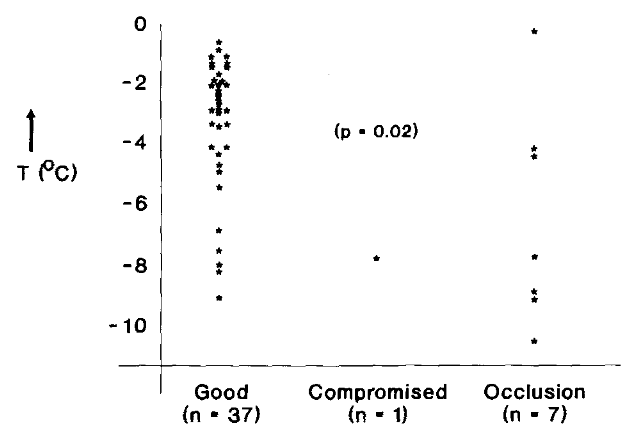

Figure 4. The lowest 30-minute differential temperature value of every replantation and revascularization registration is shown in this diagram. The good cases ranged from −9.1° to −0.7°C (mean, −3.4°C); in the compromised case the value was −7.7°C, and the vascular occlusion cases ranged from 10.5° to −0.4°C (mean, −6.5°C). The difference between the good cases and vascular occlusion cases was significant ($p = .02$).

Table 1. Laser Doppler Flow, Temperature, and Differential Temperature in 52 Recordings

Patent Vascularization (n = 41)			*Compromised Vascularization (n = 1)*			*Occluded Vascularization (n = 10)*		
LDF (PU)	*Temp (degrees)*	*DiffT (degrees)*	*LDF (PU)*	*Temp (degrees)*	*DiffT (degrees)*	*LDF (PU)*	*Temp (degrees)*	*DiffT (degrees)*
3.3	25.6	−8.0	10.0	27.5	−7.7	0.3	27.9	−0.4
12.0	32.6	−3.4				1.0	27.0	−7.7
13.0	27.2	−7.5				2.3		
13.3	26.5	−8.3				2.7	31.0	−4.5
16.0	30.2	−4.7				3.7		
16.7	29.5	−5.5				4.0	25.0	−10.5
16.7	32.8	−2.8				4.0	26.1	−9.2
16.7	33.2	−2.3				4.0	27.6	
18.0	27.6	−9.1				6.7	27.5	−4.2
23.0	33.0	−2.0				8.0	26.5	−8.9
23.3	29.8	−6.8						
23.3	30.5	−3.5						
23.3	31.1	−4.4						
23.3	33.1	−3.1						
23.3	33.4	−2.1						
26.7	30.0	−5.0						
26.7	31.1	−3.4						
28.0	30.0							
33.3	30.0	−3.0						
36.7	33.0	−2.9						
36.7	33.2	−2.0						
40.0	31.3	−2.7						
43.3	33.8	−1.4						
46.7	29.5	−0.7						
46.7	30.2	−4.2						
53.3	33.6	−1.3						
53.3	34.0	−1.4						
63.3	33.1	−1.8						
66.7	33.9	−1.5						
73.3	31.6							
80.0	31.5	−3.0						
80.0	31.9	−2.4						
80.0	34.1	−1.0						
86.7	29.9	−4.2						
86.7	33.4	−2.1						
86.7	33.7	−1.5						
100.0	33.1	−2.1						
100.0	33.7	−1.3						
113.3								
130.0								
130.0	31.9	−2.6						

The lowest value of monitoring Laser Doppler Flow (LDF), temperature (Temp), and differential temperature (DiffT) is given for all 52 postoperative replant monitoring periods divided into 3 groups, according to the clinical course.

rather expensive method and the microsurgeon requires knowledge of the method for proper use. This study shows that in the postoperative monitoring of replantations LDF is superior to thermometry in detecting vascular occlusions, although a false prediction was made by the LDF.

If one is not able to use LDF, thermometry is a reasonable alternative. In this study thermometry was monitored at the dorsal skin of the distal phalanx, in several cases dorsal and palmar temperature measurements were recorded without clear difference in temperature. Also, in experimental limb transplants in rats no difference was demonstrated in temperature recordings on different locations of the transplant.[25] It is therefore unlikely that the dorsal temperature measurements account for the difference in results between LDF and temperature in this study. Differential temperature measurements did not improve the sensitivity and specificity as was suggested by Leonard and Brennen,[10] it was even

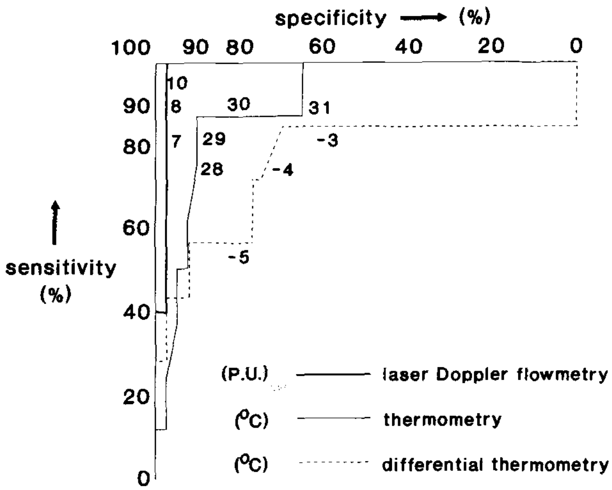

Figure 5. The sensitivity/specificity curves calculated from the studied group are shown for laser Doppler flowmetry, surface thermometry, and differential surface thermometry. The sensitivity/specificity curves are best for laser Doppler flowmetry, followed by temperature second and differential temperature as third.

inferior to measuring temperature of the replant only. If thermometry is used, one should only measure at the replanted digit.

The best alarm value of LDF (Perimed KB, Järfälla, Sweden) in replantation surgery seems to be 10 PU, with an estimated sensitivity of 93% and specificity of 94%. If a microsurgeon is eager to save his

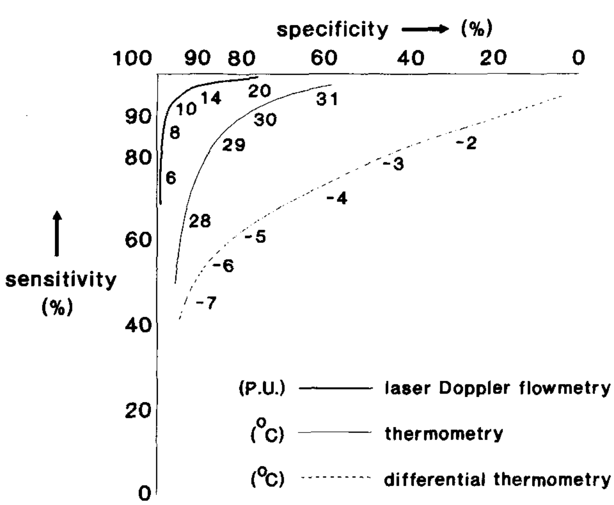

Figure 6. The sensitivity/specificity curves estimated for the total population are shown for laser Doppler flowmetry, surface thermometry, and differential surface thermometry. The sensitivity/specificity curves are best for laser Doppler flowmetry, followed by temperature second and differential temperature third. The best alarm value for surface thermometry is 29°C and for laser Doppler flowmetry 10 PU.

replants and does not mind reexploring 10% of cases unnecessarily, then the alarm value may be 14 PU. Conversely, the microsurgeon only accepts reexploration of 1 of 100 replantations unnecessarily and accepts missing 4–5 of the 20 expected vascular occlusions, the alarm value may be 6 PU. In this study we would have recognized all 11 vascular occlusions on 52 LDF recordings and we would have reexplored 1 patient unnecessarily if we had depended on LDF with an alarm value of 10 PU.

LDF equipment is available from several companies; unfortunately the equipment is different in the laser type and signal processing. Therefore comparison of results of different equipment is difficult. The alarm values mentioned by us are unfortunately only valid for the Perimed apparatus. But some studies indicate that extrapolation of laser Doppler data is possible.[26,27] Comparable results in postoperative monitoring in microvascular surgery using different apparatus were found by Clinton et al.[17] and our group.[16] Therefore, our main conclusion probably sustains for other LDF equipment.

The best alarm value of thermometry in replantation surgery seems to be 29°C, with a sensitivity of 84% and a specificity of 86%. This value is lower than the 30°C suggested by Stirrat et al.[9]

In the only false prediction of the LDF in this study, the temperature also gave a false prediction. Therefore, we do not expect improvement of sensitivity and specificity when combining LDF with thermometry.

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