Negative-Pressure Wound Therapy II: Negative-Pressure Wound Therapy and Increased Perfusion. Just an Illusion?

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Abstract

Background: A recent study demonstrated that negative-pressure wound therapy increases underlying tissue pressure. This finding is incongruous with studies using laser Doppler that show that perfusion is immediately increased on initiation of suction. This study investigated perfusion in negative-pressure wound therapy using two alternative modalities.

Methods: Radioisotope perfusion imaging was used to determine perfusion beneath circumferential negative-pressure wound therapy dressings on 20 healthy hands ($n = 20$). Ten hands received suction pressures of -400 mmHg and 10 received -125 mmHg, with the contralateral hand used as a control without any suction. Transcutaneous partial pressure of oxygen was used to determine perfusion beneath noncircumferential negative-pressure wound therapy dressings on 12 healthy legs ($n = 12$), with each volunteer being sequentially randomized to receive suction pressures of -400 and -125 mmHg, respectively.

Results: Tissues undergoing circumferential negative-pressure wound therapy demonstrated a mean reduction in perfusion of 40 ± 11.5 percent ($p < 0.0005$) and 17 ± 8.9 percent ($p < 0.0005$) at suction pressures of -400 mmHg and -125 mmHg, respectively. Perfusion reduction at -400 mmHg was significantly greater than at -125 mmHg ($p < 0.015$). In the noncircumferential negative-pressure wound therapy group, there was a mean reduction in transcutaneous partial pressure of oxygen of 7.35 ± 7.4 mmHg ($p < 0.0005$) and 5.10 ± 7.4 mmHg ($p < 0.0005$) at suction pressures of -400 mmHg and -125 mmHg, respectively. There was a tendency for greater reductions in the -400 mmHg group, but this was not significantly different from the -125 mmHg group ($p = 0.07$).

Conclusions: These findings demonstrate that perfusion beneath negative-pressure wound therapy decreases for increasing suction pressure. Thus, it is suggested that negative-pressure wound therapy should be used with caution on tissues with compromised vascularity, particularly when used circumferentially. (*Plast. Reconstr. Surg.* 123: 601, 2009.)

Negative-pressure wound therapy has revolutionized wound management, with some suggesting that it should form part of the reconstructive ladder.[1,2] The suction force applied to the tissues has been shown to immediately increase tissue perfusion,[3] and it is postulated that this is an important factor accounting for the beneficial effects of negative-pressure wound therapy.

This effect is found to occur even when applied to intact, healthy skin.[4] It is proposed that the differential pressure increases blood flow toward the foam, dilating capillary beds[3,5] and drawing off edema fluid and bacteria. Despite the many proposals, the mechanism of action of negative-pressure wound therapy remains unresolved.

A previous study at this center[6] demonstrated that tissue pressure beneath negative-pressure wound therapy is hyperbaric and that the pressure increases in a near-linear fashion for increasing suction pressures. An earlier study by Willy et al.[7] on inanimate materials (and one patient) arrived at a similar conclusion. Increased tissue pressure, however, is incongruous with increased perfusion, yet it has been shown by Morykwas et al., using laser Doppler, that perfusion is increased[3,8] up to fourfold[3] at a suction pressure of -125 mmHg.

There are conflicting reports within the literature regarding tissue perfusion. The current understanding is that the negative pressure within the foam creates a pressure gradient, which facilitates blood flow.[5] This implies that perfusion can be expected to be greatest at higher suction pressures and in close proximity to the foam. However, in the study by Morykwas et al.,[3] tissue perfusion is reported to be decreased at pressures of -400 mmHg despite the initial increase at -125 mmHg. In another study by Wackenfors et al.,[9,10] perfusion is found to be decreased adjacent to the wound edge despite being increased a few centimeters away. In contrast to both these studies, Timmers et al.[4] found that perfusion continuously increased both near and beneath the foam as suction pressure was increased - even to pressures as high as -500 mmHg.

Pressure and perfusion issues are further confounded by the fact that some surgeons recommend negative-pressure wound therapy to increase perfusion in traumatized tissues or flaps[3,4,11,12] where perfusion is equivocal, whereas others advocate that it should be contraindicated if there is any doubt about the vascularity.[13,14] Miller and Lowery[15] have pointed out that many other, less well-known studies, have found that specific suction pressures, other than the universally accepted -125 mmHg, are more favorable for wound healing.

These studies not only contradict one another, they conflict with the basic principle that increased tissue pressure results in decreased perfusion. A potential problem with these studies is the common use of laser Doppler, which may be inappropriate in this setting (as discussed later). Therefore, the need to test perfusion using an alternative modality becomes apparent. In this study, the authors evaluated perfusion beneath circumferential and noncircumferential negative-pressure wound therapy dressings at both -125 mmHg and -400 mmHg, using modalities other than laser Doppler.

Patients and methods

Circumferential Negative-Pressure Wound Therapy

To assess perfusion in this group, a prospective, randomized, controlled study using the radioisotope technetium pertechnetate was undertaken. This isotope has a half-life of 6 hours and is one of the tracers used to assess perfusion in a wide variety of medical conditions. After intravenous injection of the pertechnetate, a gamma camera is used to visualize the “time of arrival” and amount of radioactivity in the area being examined.

In 10 healthy volunteers, the palm and four fingers were placed in a sandwich-like manner between two equal-sized slabs of polyurethane foam [Vacuum Assisted Closure (V.A.C.) Kinetic Concepts, Inc., San Antonio, Texas]. The same was done on the contralateral hand (Fig. 1) and the dressings were completed according to the manufacturer’s instructions, using their adhesive occlusive drape. Both hands were then placed palm down onto the collimated gamma camera

Fig. 1. Fingers sandwiched between foam dressings.


Fig. 2. Double-detector gamma camera used in this study.

detector. Suction was applied to one side (test hand) only and, as a control, no suction was applied to the other. Half of the volunteers were randomized sequentially to receive a suction pressure of either -125 mmHg or -400 mmHg.

One minute after initiation of suction, the radioisotope was injected into the antecubital vein. This is a common method of injection of isotope and no reverse flow to the hand occurs. After 3 minutes had elapsed, the gamma camera began recording the blood pool image for 2 minutes. This image is indicative of the total amount of radioisotope that has reached the hand by means of the arterial system during this time and represents the perfusion within that hand. After the experiment, 5 days were allowed to pass, allowing complete excretion and decay of the isotope, which usually takes no longer than 60 hours. The volunteers were then brought back for an identical experiment, except that this time the contralateral hand was used as the test hand and the other as the control (i.e., a total of 20 hands were tested). This not only added power to the study but controlled for natural asymmetry that might occur because of hand dominance.

Each individual received the same suction pressure on both occasions (on the test hand). Any individual that demonstrated inconsistent findings in their test hands (i.e., increased perfusion in one test and decreased perfusion in the other test) was brought back for a third scan without any negative-pressure wound therapy dressings in place. This was to ascertain whether this finding was attributable to gross asymmetry of hand perfusion in that particular individual. The reason this technique was used rather than to conduct a pretest scan on everyone was to limit unnecessary exposure to radiation.

A subjective assessment of the image was made by a nuclear medicine physician, who was blinded to which hand had suction applied to it. An objective assessment was also carried out using the radioactivity count, which is distributed in a Poisson distribution. This activity count is the number of scintillations that the gamma camera detects and is an indication of the amount of blood that is perfusing the hand. The activity count of the area beneath the test foam was compared with the equivalent area in the control hand and expressed as a percentage of the control hand’s activity count. For accuracy during statistical analyses, however, the activity counts were used rather than the percentages.

In the test hand, as the foam collapses under suction, the hand would move 1 cm or so closer to the detector of the camera on which the hand was resting. The activity count can be influenced by the distance between the object and the detector. For this reason, a double-head gamma camera was used (e.cam; Siemens, Erlangen, Germany) with simultaneous palmar and dorsal acquisition (Fig. 2). The geometric mean of the two readings is then calculated to correct for distance discrepancies.

Tests were also carried out to assess whether the foam dressing, both in its collapsed state and its normal state, had the ability to attenuate the activity count. An activity count was acquired from a vial with a known quantity of radioactive material in the absence of any dressings. The vial was then placed in the same dressings used in the study and an activity count was obtained with and without suction, at pressures of -125 and -400 mmHg, respectively.

Noncircumferential Negative-Pressure Wound Therapy

Unlike the previous category, the radioisotope perfusion technique could not be used in this group, as the gamma camera would be influenced by perfusion detected in tissues on the opposite side of the limb, which are not beneath the negative-pressure wound therapy dressing. A transcutaneous partial pressure of oxygen sensor (TCM30; Radiometer Medical, Brønshøj, Denmark), which measures tissue oxygen tension (in millimeters of mercury), was therefore used in this group. This modality is commonly used as an indirect measure of perfusion in peripheral vascular disease.

The sensor was intended to measure the transcutaneous partial pressure of oxygen of the tissues beneath the foam, but logistically this is impossible. The overlying foam would apply pressure to the sensor, which in turn would apply pressure to the tissues and therefore influence readings. A doughnut-shaped negative-pressure wound therapy dressing was therefore created and the sensor was placed on the skin in the middle of the doughnut (Fig. 3). The hypothesis was that if suction increased perfusion to the skin beneath the foam, the tissue oxygen content to the central portion of skin would also increase; if suction decreased perfusion, the opposite would occur, provided there was no perforator beneath the central portion of skin. If negative-pressure wound therapy were to result in compression of vasculature and hypoxia in the area beneath the foam, this would not influence the central portion of skin if it had its own blood supply (in the form of a perforator). For this reason, this portion of skin was tested with a handheld Doppler device to ensure that there was no audible perforator present. This central skin was therefore reliant on the subcutaneous plexus of capillaries that course beneath the foam before reaching it.

Fig. 3. Doughnut-shaped negative-pressure wound therapy dressing with transcutaneous partial pressure of oxygen probe on exposed central skin.

The suction dressing was placed over the anterior part of both lower legs of six healthy volunteers (i.e., a total of 12 legs were tested). Each volunteer was randomized sequentially to receive a suction pressure of either -400 mmHg or -125 mmHg. The same suction pressure was used on both legs in each volunteer and each leg was analyzed independently. The experiment was carried out in a quiet room with an ambient temperature of 22°C. The individuals were sitting comfortably with both legs elevated throughout the experiment.

With the dressing on, a baseline transcutaneous partial pressure of oxygen reading was recorded every 5 minutes over a period of 15 minutes without any suction applied (four readings). Suction was then applied for 15 minutes, during which time readings were again taken every 5 minutes (four readings), with the first reading starting 1 minute after the suction was switched on (to allow for dynamic changes to settle). The suction was then switched off and, after 1 minute had elapsed, readings were taken every 5 minutes for 15 minutes (four readings). This was continued for 1¼ hours, allowing for one presuction period, two "suction-on" periods and two "suction-off" periods. The readings obtained during the suction-on periods were compared with the initial baseline (presuction) readings. All volunteers gave informed consent and the study was approved by the institutional review board.

Statistical Analysis

Each hand and leg that received negative-pressure wound therapy was treated as an independent set of data. Perfusion changes for each individual were analyzed using the Wilcoxon test. Perfusion changes for those receiving suction pressures of -400 mmHg were compared with those receiving -125 mmHg using the Mann-Whitney test with SPSS version 14 (SPSS, Inc., Chicago, Ill.). Values of $p < 0.05$ were regarded as significant.

Results

Circumferential Negative-Pressure Wound Therapy

There were three men and two women in each of the two test groups. The mean age was 33 years (range, 29 to 36 years) in the -125 mmHg group and 41 years (range, 31 to 64 years) in the -400 mmHg group. In both the -400 mmHg group and the -125 mmHg group, there was a significant mean reduction in perfusion of 40 ± 11.5 percent ($p < 0.005$) and 17 ± 8.9 percent ($p < 0.005$), respectively (Table 1). Radioactivity counts are given in Figures 4 and 5. The reduction in perfusion of the group undergoing negative-pressure wound therapy at -400 mmHg was significantly greater than the group undergoing negative-pressure wound therapy at -125 mmHg ($p < 0.015$) (Fig. 6). None of the hands demonstrated an increase in perfusion.

Table 1. Volunteer Demographics and Perfusion Reduction for Each Test Hand Undergoing Circumferential Negative-Pressure Wound Therapy ($n = 20$)

				Perfusion	Reduction
Volunteer	**Sex**	**Age (yr)**	**Suction Pressure (mmHg)**	**Left Test Hand (%)**	**Right Test Hand (%)**
1	M	35	400	59.3	48.0
2	M	35	400	47.8	40.5
3	M	36	400	40.1	36.0
4	F	31	400	45.8	26.1
5	F	29	400	37.1	18.9
6	M	34	125	29.0	9.1
7	F	64	125	14.4	19.8
8	M	31	125	30.3	19.0
9	M	42	125	1.9	22.0
10	F	36	125	19.5	15.1

M, male; F, female.

Typical images produced by the gamma camera are shown in Figures 7 and 8. On reporting the scans, the nuclear medicine physician subjectively identified 19 of 20 tests as having asymmetrical perfusion. The case reported as having symmetrical perfusion was in the -125 mmHg group.

The presence of the foam around the test vial resulted in an attenuation of the counts by only 0.01 percent. Once suction was applied, this was increased to 0.9 percent and 2.45 percent for suction pressures of -125 and -400 mmHg, respectively. This increase in attenuation is attributed to the increasing density of the foam as suction increases. The attenuation was factored into calculations.

Noncircumferential Negative-Pressure Wound Therapy

The mean age of the volunteers was 34 years (range, 29 to 35 years). There was one man and two women in each group. During the period when suction was applied, there was an overall reduction in transcutaneous partial pressure of oxygen of all 12 legs (mean ± SD, 6.29 ± 6.44; $p < 0.0005$). Individual group analysis revealed that the mean of the reductions in transcutaneous partial pressure of oxygen was 7.35 ± 7.4 mmHg ($p < 0.0005$) in the -400 mmHg group and 5.0 ± 4.67 mmHg ($p < 0.0005$) in the -125 mmHg group. Figure 9 graphically illustrates a typical example of one of the tests, demonstrating the various time periods. Although there was a tendency for the mean reduction in the group undergoing suction pressures of -400 mmHg to be greater than in the group undergoing suction pressures of -125 mmHg, this was not statistically significant ($p = 0.07$).

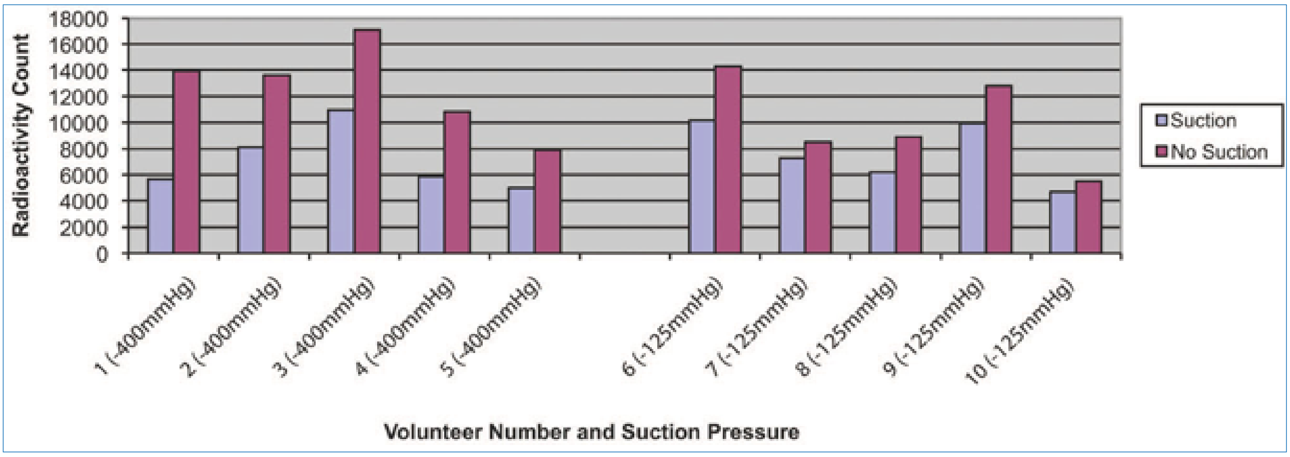

Fig. 4. Comparison of left test hand and right control hand.

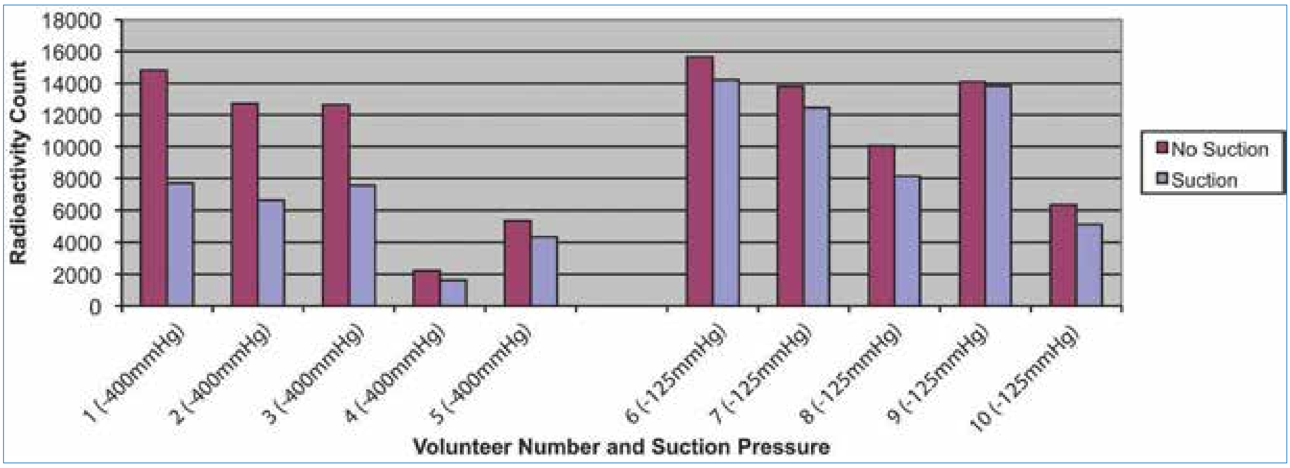

Fig. 5. Comparison of right test hand and left control hand.

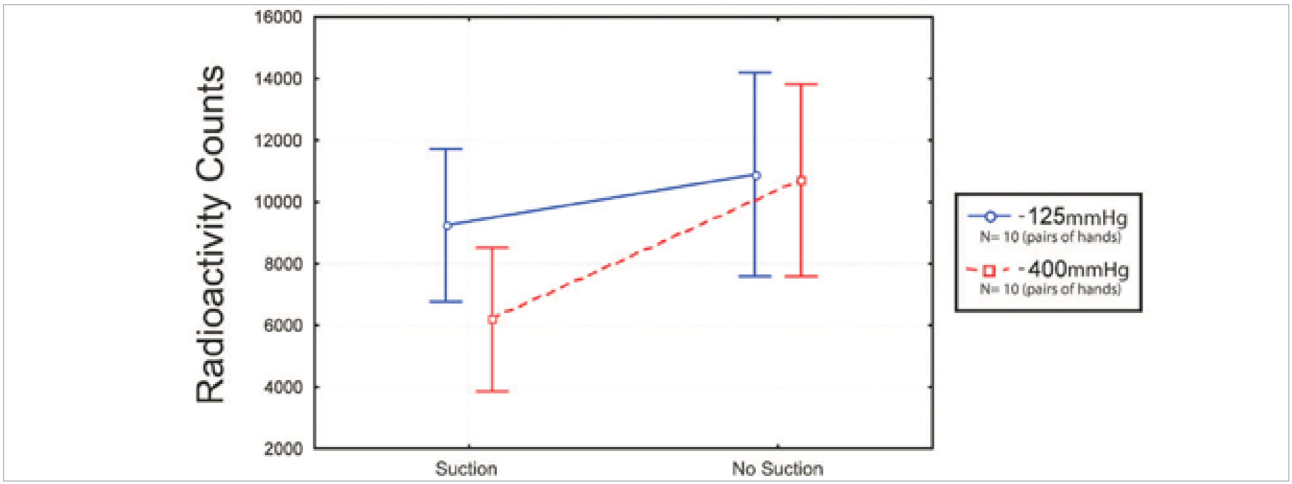

Fig. 6. Mean counts and SD for both suction pressure groups. The reduction caused by -400 mmHg is significantly greater than that caused by -125 mmHg ($p < 0.0005$).

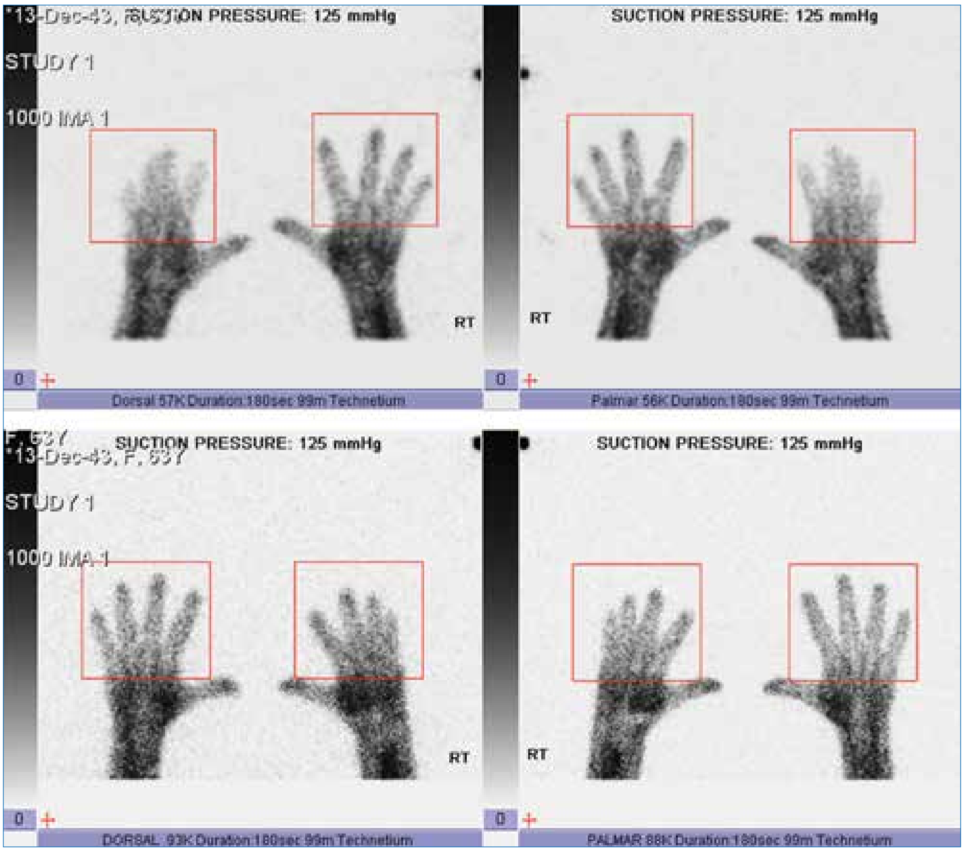

Fig. 7. (*Above*) Dorsal and palmar gamma camera views of both hands of a volunteer with left hand undergoing suction pressure of -125 mmHg. (*Below*) Equivalent views of the same volunteer, this time with the right hand undergoing suction pressure of -125 mmHg.

When the results of each lower limb were examined individually, all 12 legs demonstrated a reduction in transcutaneous partial pressure of oxygen regardless of suction pressure (Tables 2 and 3). It was also noted that the means of the tissue oxygen tension after the suction was switched off for the first time (62.4 mmHg) and when it was switched off for the second time (63.3 mmHg) were both significantly less (p = 0.02 and p = 0.03, respectively) than the prenegative-pressure wound therapy mean (65.4 mmHg).

Discussion

This study demonstrates that there is a substantial decrease in tissue perfusion beneath negative-pressure wound therapy dressings, and that this decrease is greater for increasing suction pressures. This is in keeping with the recent findings that negative-pressure wound therapy generates proportionately increasing tissue pressures for increasing suction pressures.[6,7]

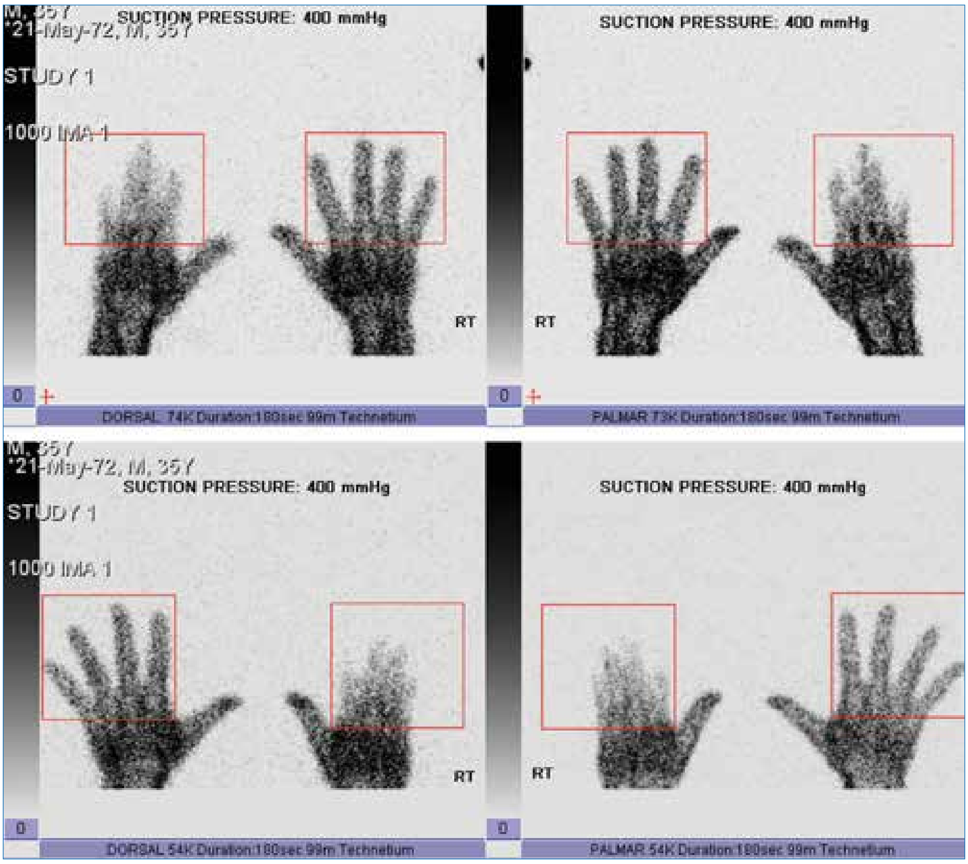

Fig. 8. (*Above*) Dorsal and palmar gamma camera views of both hands of a volunteer with left hand undergoing suction pressure of -400 mmHg. (*Below*) Equivalent views of the same volunteer, this time with the right hand undergoing suction pressure of -400 mmHg.

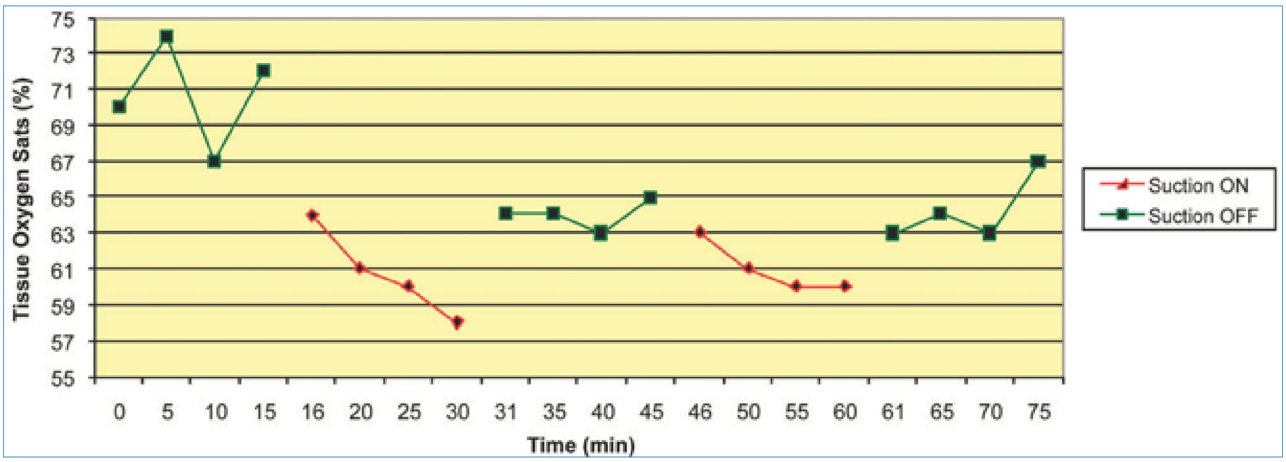

Fig. 9. Typical example of transcutaneous partial pressure of oxygen (*TcPO$_2$*) fluctuations at -125 mmHg illustrating testing time periods. The readings obtained during the suction-on periods were compared to the initial baseline (presuction) readings.

These results conflict with other studies, using laser Doppler, that show increased perfusion beneath negative-pressure wound therapy dressings.[3–5,9,10] This questions the reliability of laser Doppler in assessing perfusion in the setting of negative-pressure wound therapy. The assessment of perfusion beneath negative-pressure wound therapy dressings is difficult, and the laser Doppler device appears to be the confounding factor responsible for the conflicting reports. For example, a criticism of the study by Timmers et al.[4] is that some of the probes were placed beneath the foam of the vacuum dressing. This may cause inaccuracies because the probe is pushed against the tissues as the foam collapses. This force applied to the tissues not only affects perfusion but may interfere with readings because laser Doppler is particularly sensitive to movement. Placing the probe just outside the negative-pressure wound therapy dressing, as done by Morykwas et al.[3] and Wackenfors et al.,[9,10] is also not a true indication of what is occurring within the wound, where readings would have been more relevant.

Radioisotope perfusion imaging, in contrast, avoids these problems, as there is no sensor within the foam and yet a clear impression

Table 2. Reduction in Transcutaneous Partial Pressure of Oxygen for Each Leg Undergoing Negative-Pressure Wound Therapy at 400 mmHg (*n* = 6)

Volunteer	Leg	Suction at 400 mmHg	Mean $TcPO_2$ (%)	SD	Significance of Difference (*p* Value)
1	Left	Off	67.42	1.564	<0.0005
		On	63.75	2.188	
	Right	Off	78.50	2.646	<0.0005
		On	71.00	5.182	
2	Left	Off	64.17	5.997	<0.0005
		On	50.00	8.053	
	Right	Off	59.25	1.658	0.003
		On	52.88	4.155	
3	Left	Off	52.83	4.196	0.083*
		On	50.25	1.982	
	Right	Off	78.0	2.646	<0.0005
		On	71.00	5.182	
Combined means	All legs	Off	66.78	10.327	<0.0005
		On	59.81	10.016	

$TcPO_2$, transcutaneous partial pressure of oxygen.
*p = not significant.

Table 3. Reduction in Transcutaneous Partial Pressure of Oxygen for Each Leg Undergoing Negative-Pressure Wound Therapy at 125 mmHg (*n* = 6)

Volunteer	Leg	Suction at -125 mmHg	Mean $TcPO_2$ (%)	SD	Significance of Difference (*p* Value)
4	Left	Off	66.33	3.774	0.001
		On	60.88	1.885	
	Right	Off	63.50	4.359	0.043
		On	59.75	2.605	
5	Left	Off	57.25	3.467	0.01
		On	53.25	2.252	
	Right	Off	52.50	2.876	0.001
		On	44.88	5.817	
6	Left	Off	67.25	3.079	0.008
		On	62.75	3.615	
	Right	Off	57.17	3.738	0.008
		On	52.00	3.854	
Combined means	All legs	Off	60.67	5.899	<0.0005
		On	55.59	6.777	

$TcPO_2$, transcutaneous partial pressure of oxygen.

is obtained of tissue perfusion beneath the foam. It also allows for visualization of the whole area beneath the foam - and also a considerable area not covered by the foam - unlike the laser Doppler device, which provides a reading for a specific point of contact. To test perfusion beneath noncircumferential negative-pressure wound therapy, the doughnut-shaped dressing used appears to be a reliable model, which avoids applying pressure to the sensor used.

Many variables influence the amount of positive pressure that negative-pressure wound therapy generates in the tissues (e.g., consistency of the underlying tissues),[6,9,10] which in turn is affected by tissue type, anatomical location, the amount of edema present, fibrosis, and other factors. The tissue pressures generated by negative-pressure wound therapy in other studies will therefore be different for a specific suction pressure; consequently, comparing different studies' results on perfusion for a specific suction pressure is not possible. This provides another explanation for the conflicting reports on perfusion at specific suction pressures.[3,4] This study suggests that, at *any* suction pressure, perfusion is decreased.

A hypothesis is suggested that may explain why the laser Doppler device is inappropriate in this setting and that also explains the conflicting findings seen in many studies. Although a laser Doppler result ("perfusion units") is clinically correlated as "perfusion," it is derived by multiplying blood velocity by the concentration of red blood cells. When there is a physiologic decrease in perfusion, the contraction of precapillary sphincters decreases the amount of blood entering a particular capillary bed. This results in a decrease in both the concentration and velocity of red blood cells. As the laser Doppler reading is a product of these two variables, it reflects decreased perfusion units, which is correctly interpreted as decreased perfusion.

However, there are fundamental differences in a physiologic decrease in perfusion compared with a decrease as a result of an external compression force. In the latter, all vessels, regardless

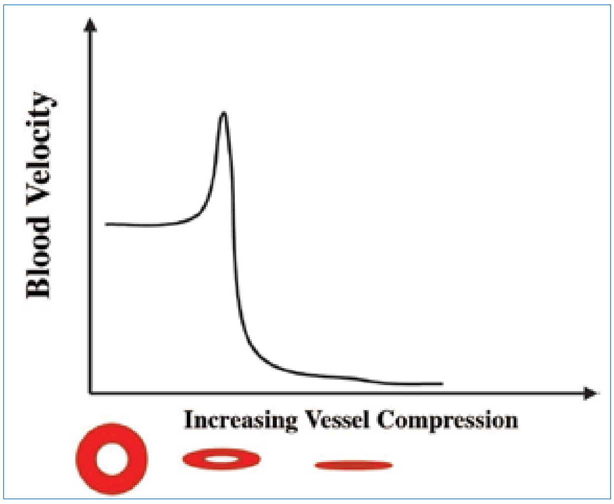

Fig. 10. Expected course of blood velocity as the vessel is compressed, demonstrating a sharp increase (velocity spike), followed by a sudden decrease as the point of occlusion is approached.

of whether they are before or after the capillary sphincter, are compressed, resulting in a narrower lumen. As the tissue pressure rises, vessel diameter decreases; consequently, velocity of the blood within the vessel increases. This principle of physics, permitting the transfer of the same volume through a narrower lumen, is known as the equation of continuity. The velocity will increase sharply as the vessel narrows, until it reaches a point where the lumen is occluded, at which time the flow and velocity will rapidly decrease and then cease.

An instrument that measures velocity within a vessel that is progressively compressed will demonstrate a sharp velocity "spike" followed by a rapid decrease in velocity (Fig. 10). This appears to be what the laser Doppler traces of Morykwas et al.[3] demonstrated at

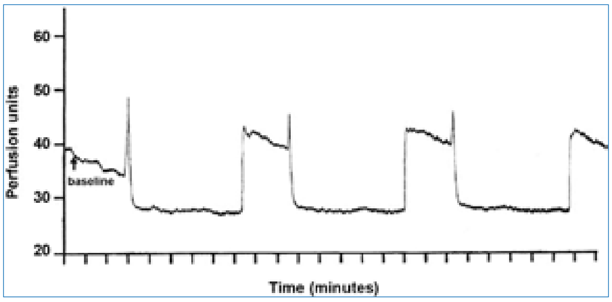

Fig. 11. Laser Doppler trace of perfusion (negative-pressure woundtherapy at -400 mmHg) demonstrating velocity spikes just before perfusion decreasing, implying that the trace reflects blood velocity rather than perfusion. (Reprinted with permission from Morykwas MJ, Argenta LC, Shelton-Brown EI, et al. Vacuum-assisted closure: A new method for wound control and treatment: Animal studies and basic foundation. *Ann Plast Surg*. 1997;38:553–562.)

pressures of -400 mmHg (Fig. 11), implying that the laser Doppler device was indeed measuring velocity changes rather than perfusion changes. The laser Doppler traces of others[9,10] who also reported decreased perfusion resulting from negative-pressure wound therapy also demonstrate velocity spikes before the decrease in the so-called perfusion. Under physiologic conditions, changes in velocity are mirrored by changes in perfusion, but not when these changes occur because of the presence of an external compressive force (such as a negative-pressure wound therapy dressing), where an increased velocity may occur simultaneously with a decreased perfusion.

Similarly, if a vessel were to be occluded only partially, the velocity would rise and this increase would be sustained until such time as the vessel returned to its "normal" diameter (Fig. 12). Therefore, if a vessel were to be occluded partially, with a lower suction pressure, such as -125 mmHg, the flow velocity (and resultant Doppler reading) would increase and remain elevated during this period, until the suction was terminated. This too correlates with the laser Doppler readings reported by Morykwas et al.,[3] who found an apparent increase in perfusion at -125 mmHg (Fig. 13). Other studies have shown similar results.[4,9,10] The fact that the diameter of the underlying vessels has changed is not factored into the calculation of the laser Doppler device, which records an effect of increased velocity only, which is erroneously interpreted as increased perfusion.

The suggestion that laser Doppler reflects velocity changes, rather than perfusion changes, also provides an explanation for the inconsistencies demonstrated by other studies on perfusion. Wackenfors et al.[9,10] found perfusion to be increased a few centimeters from the wound edge but decreased in close proximity to the wound edge. If laser Doppler examination is a true measure of perfusion, this finding seems illogical; however, if laser Doppler examination is a measurement of blood velocity, the findings are more consistent. The higher pressure in the tissue in close proximity to the foam is likely to have occluded most of the capillaries, with the laser Doppler correctly recording reduced perfusion. However, as the distance from the foam increases, the increased tissue pressure dissipates rapidly, and the diameter of the vessels increases

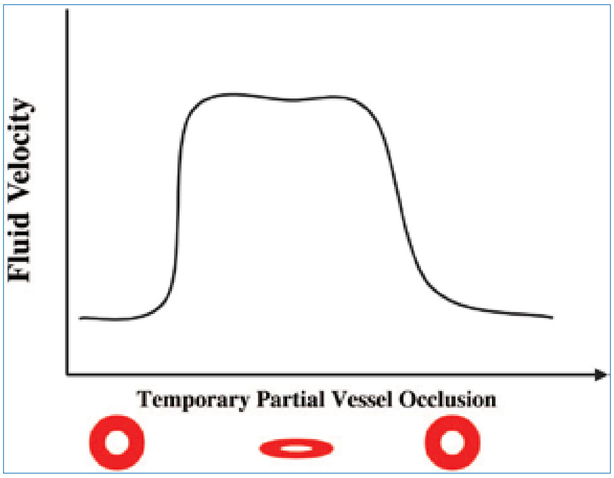

Fig. 12. Expected course of blood velocity if the vessel is occluded only partially for a period and then compression is released to allow for normal flow. Velocity increases during the period of compression in accordance with the Equation of Continuity.

gradually, eventually reaching normal diameter some distance from the foam. Consequently, blood velocity would be increased in the partially compressed vessels (incorrectly perceived as an increase in perfusion by the laser Doppler), and would gradually decrease to "normal" levels the farther the measurements are taken from the foam. This proposal explains the perfusion findings of both Morykwas et al.[3] (at different suction pressures) and Wackenfors et al.[9,10] (at varying distances from the foam).

A limitation of this study is that it was performed on intact skin rather than open wounds. However, the study by Timmers et al.,[4] which concluded that negative-pressure wound therapy increases perfusion, was also performed on intact skin. Furthermore, a preliminary study on perfusion in injured hands with skin loss (receiving negative-pressure wound therapy) at this institution has revealed findings identical to those in this study.

As with most perfusion studies, another limitation of this study is that each experiment was carried out over a period of a few minutes, which may not be a true indication of perfusion changes over a longer period. However, in a previous study, it was noted that after a 48-hour period of negative-pressure wound therapy, the majority of wounds still had tissue pressures higher than baseline levels.[6] This implies that perfusion is likely to also be reduced in these cases. Furthermore, in a pilot study, also using radioisotope scanning, the perfusion in an injured hand decreased immediately on application of negative-pressure wound therapy and remained so when the scan was repeated at 48 hours with suction still on.

Conclusion

Negative-pressure wound therapy decreases perfusion beneath negative-pressure wound therapy dressings. Greater suction pressures result in a proportional reduction in perfusion. This is in keeping with the findings of previous work[6,7] indicating that tissue pressure is increased beneath all configurations of negative-pressure wound therapy dressings.

It is suggested that use of the laser Doppler device is an inappropriate

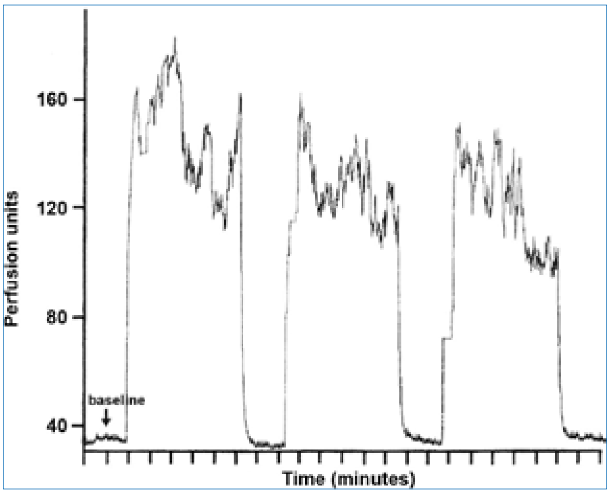

Fig. 13. Laser Doppler trace of "perfusion" (negative-pressure wound therapy at -125 mmHg). Tissue pressures increase but to a lesser extent than with negative-pressure wound therapy at -400 mmHg, resulting in moderate compression of vessels and an increase in velocity. (Reprinted with permission from Morykwas MJ, Argenta LC, Shelton-Brown EI, et al. Vacuum-assisted closure: A new method for wound control and treatment: Animal studies and basic foundation. *Ann Plast Surg.* 1997;38:553–562.)

method for measuring perfusion beneath negative-pressure wound therapy dressings, because of the effect that blood velocity has on readings. This may explain the conflicting findings of studies using this device.

This study raises concern regarding the role of negative-pressure wound therapy in tissues with compromised perfusion. As perfusion is found to be decreased in this study, it is suggested that these dressings should be applied with caution on poorly perfused tissues.

Acknowledgements

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