POSTEXERCISE HYPOTENSION IS VOLUME-DEPENDENT IN HYPERTENSIVES: AUTONOMIC AND FOREARM BLOOD RESPONSES

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Postexercise hypotension after Resistance Exercise in elderly

Abstract
The purpose of this study was to evaluate the effect of two sessions of resistance exercise with different volumes on postexercise hypotension (PEH), forearm blood flow (FBF) and cardiac autonomic balance in hypertensive elderly woman. The study was conducted with sixteen hypertensive elderly (25.7±3kg/m², 55.5±3years) subjected to three experimental sessions, ie, a control session (CS), exercise with a set (S1) and exercise with three sets (S3). For each session, the subjects were evaluated before and after intervention. In the pre-intervention period, blood pressure (BP), FBF and autonomic balance were measured after 10 minutes of rest in the supine position. Thereafter, the subjects were taken to the gym to perform their exercise sessions or remained at rest during the same time period. Both S1 and S3 comprised a set of ten repetitions of ten exercises, with an interval of 90 seconds between exercises. Subsequently, the measurements were again performed at 10, 30, 50, 70, and 90 minutes of recovery (post-intervention) in the supine position. Post-exercise hypotension (systolic/diastolic) was greater in S3 than in S1 (-26±4/-14±5 mmHg versus -18±5/-8±5mmHg, p<0,05). Similarly, FBF and cardiac autonomic balance increased in both sessions, being more evident in S3 than in S1 (4.98±0.32 vs. 4.36±0.27 ml.min-1100ml-1, p<0,05; and LF/HF=1.69±0.225 vs. 1.37±0.13 p<0,05, respectively). We conclude that a single resistance exercise session with three series were able to promote higher PEH in hypertensive women, and this phenomenon was accompanied by increased forearm blood flow and increased cardiac autonomic activity.

Keywords: Hypertension; Resistance exercise; autonomic control, training

INTRODUCTION
Hypertension (HP) is a multifactorial and multicausal syndrome characterized by high blood pressure (BP) levels, usually associated with metabolic, hormonal, and structural disorders (27,32,47). Mild hypertension is defined as blood pressure level of 140-159 mmHg systolic and/or 90-99 mmHg diastolic (37). This condition augments risk for vascular events, such as coronary heart disease, stroke, heart failure, peripheral artery disease, chronic kidney disease, and dementia (17). Approximately 1 billion individuals worldwide are affected by HP, and these numbers are increasing with time, being responsible for approximately 7.6 million deaths per year (21). Moreover, alarming data revealed a 22% prevalence of hypertension in a Brazilian population (individuals aged ≥ 18 years)(39)
Hypertensive individuals have a decreased blood flow and vascular conductance at rest, which reduces its vasodilator reserve, with consequent alteration of vasodilator responses (11). Age-related endothelial dysfunction, vascular remodeling and increased arterial stiffness contribute to the increased prevalence of hypertension among the elderly (14).

The ability of exercise to reduce blood pressure (BP) is well established (10,32). Several agencies have procedures that guide the exercise prescription for elderly. In these documents, much attention is given to the cardiovascular and oesteoarticular safety, particularly concerning to training intensity. The American College of Sports and Medicine - ACSM (2004) (31) suggests that resistance exercise (RE) should be prescribed to hypertensive patients with moderate loads (60% 1RM). The American Heart Association (AHA) has proposed that healthy older adults could perform exercises at intensities above 60% 1RM (7). Additionally, cardiac patients, regardless of age, could perform exercises at lower intensities. However, no consideration is taken as the best prescription volume of exercise to promote Post Exercise Hypotension (PEH) in elderly. This is important since the cardiovascular responses in multiple series can be higher compared to single series (19).

There are obvious gaps regarding the best prescription of RE, mainly concerning to population and which mechanisms are involved in post-exercise responses, because of the diversity and variations in the research protocols with respect to intensity, number of sets, interval and method of BP measurement (5,9,18,23,27–30,35,36,46,47). However, few studies (8,24,29) have evaluated the cardiovascular and hemodynamic responses to exercise.
From these, only one investigated the effects of different training volumes in PEH (24). However, in this study only BP was used as a hemodynamic parameter. In addition, the protocol used was composed of just four exercises, reducing its external validity, since in practical context it tends to use more variety of exercises. Thus, investigation of the mechanisms by which different exercises volumes affect BP responses in hypertensive elderly is still a pertinent and relevant gap to research.

We hypothesized that resistance exercises with higher volumes will promote better pressure and vascular responses in hypertensive elderly. Given the above, the purpose of this study was to investigate BP, FBF, vasodilatory capacity and Heart Rate Variability in hypertensive elderly patients after a session of resistance exercise with different volumes.

METHODS

Subjects

The study was conducted with 16 elderly subjects with mild hypertension, according to the classification proposed by the ACSM (31). They were all physically active and participated regularly for at least three months of the program of resistance exercise at the Federal University of Paraíba. In order to participate in the study they should have had a minimum age of 50 and maximum of 60 years old, assiduously practicing physical exercise for three or more times per week and presenting only hypertension as cardiometabolic disease. All were users of hypertensive medications, but these included only
angiotensin-converting enzyme inhibitors and diuretics. The subjects’ characteristics are shown in Table 1.

(TABLE 1)

All subjects were informed about the procedures that would be made in data collection and, prior to their participation, signed consent pursuant to resolution 196/96 National Health of Brazil for human experiments. All of them agreed to participate in the methodological procedures proposed in the research, approved by the ethics committee of the Center for Health Sciences UFPB, under the protocol number 135/10.

Experimental Approach to the Problem

Familiarization session and maximum load test: before the experimental sessions, the elderly underwent a familiarization session (a series of 10 repetitions of each exercise with the minimum weight allowed by the machines). Three days later they underwent a 1RM test to leg extension, front pulley, leg 45, fly, knee flexion, low row, adductor, triceps, plantar flexion in the leg 45 and biceps following the protocol (20). Seven days after we performed a re-test to legitimize the validity of previous results. The maximum load was estimated after 3 attempts for each exercise and with a minimum rest period of 3 minutes between each attempt. After 48 hours, a re-test was performed to obtain the greatest workload. The reliability was considered good when a difference of 5% was found between the tests. During the tests, the air temperature was kept...
stabilized between 21 and 24 °C and relative humidity ranging between 50–60%. No dietary advice was provided, and participants were asked to maintain their normal caloric intake during the study. Participants were instructed to refrain from any other regular exercise during all of the entire study period.

**Experimental sessions:** Hypertensive patients underwent three experimental sessions: control session (CS), a set of exercises with 50% of 1RM (S1), and exercises with three sets at 50% 1RM (S3), always performed between 7 and 9 a.m. with a break of at least seven days. The order was determined individually and randomly using the website Research Randomizer (www.randomizer.org), so that each subject had its own order to carry out the three study sessions. Before the study, they were instructed to not perform physical activities 48 hours before the experimental sessions.

For each session, the subjects were evaluated pre-and post-intervention. In pre-intervention, at rest in the supine position, was recorded BP, forearm blood flow (FBF), heart rate, vasodilatory capacity and cardiac autonomic modulation. They were later taken to the gym, where they performed the exercise sessions (S1 and S3) or CS in each of the equipment during the same time of the sessions exercise. Both S1 and in S3 followed the (31) protocol for variables such as intensity, number of repetitions, time interval and number of exercises, differing only in the number of series. Thus, individuals performed one or three sets of 10 repetitions of 10 exercises mentioned above, with an interval of 90s between exercises for the load of 50% 1RM. During the execution of the sessions, the *valsalva* maneuver was constantly discouraged,
without any stimulus to motivate the subjects. In sequence, they returned to the laboratory for the post-intervention period, where they were placed in the supine position for measurements, performed at five times over 90 minutes of recovery. The experimental protocol could be seen in Figure 1.

(Figure 1)

Procedures

Blood Pressure: BP measurements were performed at every heartbeat via photoplethysmography using the Finometer PRO (Finapress Medical Systems BV, Amsterdam, the Netherlands); the measurement was obtained by placing the cuff on the middle finger of the nondominant hand. Each subject was connected to the Finometer device, and BP was recorded continuously for a period of 10 min. After a recording period of 2 min, the Finometer offers the option to perform a return-to-flow systolic calibration (this is an individual patient level adjustment, which calibrates the upper-arm pressure of each specific subject with her finger pressure) (40). Highest precision in BP readings is obtained only after this calibration in the dominant upper-arm, always before exercise sessions. The mean systolic blood pressure (SBP) and diastolic blood pressure (DBP) were determined from the mean BP of the 10 min of the recording. The waveform generated by the equipment was acquired on a computer, at a sampling frequency of 500 Hz, using a data acquisition system (WinDaq DI-720; Dataq Instruments Inc, Akron, OH, USA).
Heart Rate (HR): To determine heart rate an electrocardiogram (ECG) was used. Three electrodes were placed in the patient's chest, in DII. The acquisition and visualization of the ECG signal was obtained through WINDAQ Acquisition software (DATAQ Instruments - Akron, Oshio, USA).

Forearm blood flow (FBF): The forearm blood flow was assessed by venous occlusion plethysmography. For this evaluation, it was placed two cuffs in the non-dominant arm, one around the wrist and the other on the upper arm, which were connected to the plethysmograph (Hokanson AG 201, Washington, USA). The cuff placed around the wrist was inflated to a supra-systolic mode a minute before of starting the measurements. At 10 seconds, the arm cuff was inflated above the venous pressure for 7-8 seconds. Changes in the circumference of the forearm were perceived by a silastic tube of mercury, placed two inches away from the humerus-radial and connected to the plethysmograph. Elected to measure blood flow in the forearm, since Endo et al (15) mentions in their paper that the post-exercise hypotension is directly associated with an increased total vascular conductance.

Vasodilatory capacity: The vasodilatory capacity of the forearm was evaluated by reactive hyperemia technique. To this end, the cuff located in the arm of the volunteer was inflated at a supra-systolic level for three consecutive minutes, then the flow measurements were performed up to three minutes after the occlusion period to assess the vasodilatory capacity compared to its baseline.
Heart Rate Variability: For autonomic evaluation, ECG (TEB, D10) and respiratory movements (thoracic belt-UFI, Pneumotrace II) were recorded for 10 min with a sample frequency of 500Hz per channel. R–R intervals and respiratory time series were determined by PRE software (Calcolo Segnali di Variabilità Cardiovascolari—20/06/95, Dipartimento di Bioingegneria Del Politecnico di Milano). An autoregressive spectral analysis of R–R variability was performed using LA software (Programma di Analisi Lineare—14/12/1999, Dipartimento di Scienze Precliniche, Universita Degli Studi di Milano). Briefly, on stationary segments of the time series, autoregressive parameters were estimated by the Levinson–Durbin recursion, and the order of the model was chosen according to the Akaike's criterion. An autoregressive spectral decomposition was performed, and the components were assigned based on their central frequency as low- (LFR–R, 0.04–0.15 Hz) and high-frequency (HFR–R, 0.15–0.4 Hz). HF power was considered in dependence to a significant coherence with the respiratory spectrum. LFR–R and HFR–R components were reported in normalized units (nu), which represent the relative value of each power component in proportion to the total power minus the very low-frequency component (VLFR–R, 0–0.04 Hz). Normalized LHR–R and HFR–R components were accepted, respectively, as markers of the predominant cardiac sympathetic and parasympathetic modulations.
Sample Size Estimation

The determination of sample size was made as proposed by Eng (2003), utilizing the software Gpower 3.1.0 (Franz Faul, Universitat Kiel, Germany). For this, it was adopted a statistical power of 0.80 and an alpha error of 0.05. It was estimated a difference in PEH of 7 mmHg between exercises intensities, with residual standard deviation of 4 mmHg, based in Polito e Farinatti (2009). As a result, it was determined a minimum of 10 subjects. The study began with 17 volunteers and, ultimately, 16 hypertensive completed the experimental protocol. There was a dropout due to family health problems.

Statistical Analysis

The normality of the data and differences between the standard deviation were verified by Shapiro-Wilk and Levine tests, respectively. The absolut baseline data were compared by one-way ANOVA for repeated measures. To analyze the variables over 3 time points (pre x S1 x S3), we used the two-way ANOVA for repeated measures. The post hoc Newman-Keuls test was used to locate the differences in analysis when the observed value of p <0.05. For all analyzes, the level of significance was p <0.05. Data are presented as mean and standard deviation. Statistical analysis was performed using the statistical program STATISTICA for WINDOWS (ver.4.3, StatsoftInc., 1993, Tulsa, OK, USA).
RESULTS

All subjects completed the study without any adverse events. They presented similar basal values for BP, HR, FBF, reactive hyperemia and heart rate variability with no statistically significant differences identified. All of them used antihypertensive medication. The subjects’ characteristics are shown in Table 1.

(TABLE 1)

The BP responses after three experimental sessions are shown in figure 2. Procedures S1 and S3 were able to promote a significant reduction in systolic, diastolic and mean BP at 90 minutes post-intervention compared with both the control session and the baseline values for S1 and S3. Moreover, the reduction in BP was higher in the recovery period after S3 in comparison with S1. The greatest reduction occurred at 90 minutes of S3 and S1 procedures relative to baseline (SBP = -26±4 vs -18±5 mmHg; DBP = -14±5 vs -8±5 mmHg and MBP = -28±4 vs. -18±4 mmHg, p<0.05, respectively).

(FIGURE 2)

The HR S1 did not change over time. Differently, in S3, HR remained increased compared to baseline until 50 minutes postexercise, and also different relative do SC and S1 (figure 3, panel A). This increased HR during recovery of S3 was accompanied by higher BF values and LF / HF.
Forearm blood flow (FBF) showed a significant increase in exercise sessions at all post-intervention measurements. Comparing the exercise protocols, it was found that forearm blood flow was always higher in S3 ($P<0.05$).

Following the same behavior observed for FBF, reactive hyperemia was higher comparing S3 to S1.

**DISCUSSION**

Data from this study confirms the premise that RE are able to promote PEH in hypertensive elderly and demonstrates that there are differences regarding the exercise’s volume, since the magnitude of PEH was significantly greater for exercises with higher volume. Moreover, this study contributes to the literature regarding to related mechanisms of PEH in hypertensive elderly, as it was observed hypotension was accompanied by an improvement in FBF and Forearm Vascular Resistance (FVR) during the recovery period.

In spite of RE increasingly gain notoriety for its ability to promote reduction of BP after exercise, to make assertions about the best prescription for this type of exercise in promoting PEH is still something rash (6,13). This stems from the wide variety of experimental designs reported in the literature on differences in training models (conventional or circuit or “adapted”), time interval
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(30 to 120 sec.), intensity (medium to high), number of repetitions (8 to 20), number of exercises, analytical methods for measuring BP (clinic, ambulatory) and sample (young, middle-aged adults, elderly, healthy and/or hypertensive) (1,8,16,24,25,29,45,47). Thus, generalizations are inappropriate. Of the studies with hypertensive subjects, the values obtained range from -2 to -13 mmHg for SBP and -2 to -7.9 mmHg for DBP (27,34,44).

Our study has found hypotension values greater than those, even when the exercise sessions were undertaken with a single set, with SBP and DBP values of -18±5 mmHg and -8±5 mmHg, respectively. Furthermore, when exercise sessions were conducted with three sets, these values were even greater: -26±4 mmHg for SBP and -14±5 mmHg for DBP. Although these values are quite pronounced when compared with literature, we found similar values of PEH for the S1 protocol with other studies in our laboratory with hypertensive elderly patients, also with three sets and in similar moderate intensity exercise protocol (2–4).

The results corroborate of others (24,33,38,43). These studies showed greater and longer post exercise hypotension with programs with higher volumes (i.e., 1 vs 3 repetitions, with just 4 sets; 5 vs. 6 exercises in a sequence; 6 vs. 10 sets in only 1 exercise; 1 vs. 2 sets in a circuit approach, respectively).

The mechanisms behind this PEH needs discussion. A possible explanation is that the high training volume could have elicited an acute cardiovascular imbalance by affecting plasma volume, thereby cardiac output and systolic volume (34). Additionally, since concentric failure occurs more
frequently with increased training volume, recruitment of additional motor units requires a progressive activation of the sympathetic nervous system to maintain training volume and intensity (42). Finally, these findings may have been caused by greater activation of mechanoreceptors, and arterial baroreflex, due to a reduction in blood flow to the active muscles and an increase in peripheral vascular resistance induced by a mechanical occlusion of blood flow (34).

The results relative to HRV showed that greater number of sets promote a greater cardiac stress, corroborating data of Figueiredo et al (2015), Rezk et al., (2006), (22) and Texeira et al., (2011). Theoretically, a sympathetic activation could increase BP. However, previous data suggests that an increased cardiac sympathetic nerve activity results in compensatory reflex vasodilatation (5,29,41). The increased blood flow and hyperemia in the present work and in Collier et al (2010) (12) could ratify this phenomenon.

The fact that our study was carried out in a university fitness center that has training programs targeted exclusively for the elderly population enabled us to provide data for this population of hypertensive. We value the safety of patients, following protocols already used in other study(2), respecting variables such as intensity, volume and interval. This demonstrates that our work has external validity, since it shows that even trained people (a population that is more difficult in achieving hypotensive responses due physiological adaptations(26)) can benefit of regular training (since it’s logical for this segment of population be engaged in an training programme).
CONCLUSION

In this way, a single resistance exercise session with three series were able to promote higher PEH in hypertensive women, and this phenomenon was accompanied by increased forearm blood flow and increased cardiac autonomic activity.

PERSPECTIVES

The findings of this study demonstrated a significant post exercise hypotensive response to RE in hypertensive women. The extent of the cardiac response was directly related to training volume such that higher volumes of RE elicited a greater response in BP and HRV. Our work shows high external validity, since the population of the study included individuals using antihypertensive medications, well-established strategy among hypertensives. Additionally our data shows that in elders, physical activity induces cardiovascular and hemodynamic responses not significantly different from those induced in adult. Further studies with a higher number of volunteers and that can evaluate the effect of a chronic resistance protocol on BP are necessary to improve the prescription of resistance exercise in elderly individuals.

Sources of Funding
None.

Conflict(s) of Interest/Disclosure(s)
None.
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References


12. COLLIER, S and DIGGLE, M. Changes in arterial distensibility and flow-mediated dilation after acute resistance vs. aerobic exercise. *J Strength...
Postexercise hypotension after Resistance Exercise in elderly


25. Melo, CM, Alencar Filho, AC, Tinucci, T, Mion, D, and Forjaz, CLM.


36. Santana, H a P, Moreira, SR, Neto, WB, Silva, CB, Sales, MM, Oliveira, VN, et al. The higher exercise intensity and the presence of allele I of


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Table 1. Anthropometric, biochemical, and hemodynamic characteristics at baseline.

<table>
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<th>Hypertensive (n=16)</th>
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<tr>
<td><strong>Age (years)</strong></td>
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<tr>
<td><strong>BMI (Kg/m²)</strong></td>
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<tr>
<td><strong>Glucose (mg/dL)</strong></td>
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<td><strong>Triglycerides (mg/dL)</strong></td>
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<td><strong>Cholesterol (mg/dL)</strong></td>
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<tr>
<td><strong>HDL (mg/dL)</strong></td>
</tr>
<tr>
<td><strong>LDL (mg/dL)</strong></td>
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<td><strong>Medicines</strong></td>
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<table>
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<th>S3</th>
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<tr>
<td><strong>SBP (mmHg)</strong></td>
<td>145 ± 3</td>
<td>147 ± 4</td>
<td>143 ± 3</td>
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</table>

Novelty and Significance

What Is New?
- Aerobic exercise on a regular basis reduces blood pressure in resistant hypertension.
- Aerobic exercise improves physical performance in resistant hypertension.
- A training of moderate intensity is well tolerated by resistant hypertensions.

What Is Relevant?
- A low responsiveness to pharmacological therapy does not mandatorily mean a low responsiveness to exercise.

Exercise should be included in the therapeutic approach to resistant hypertension.

Summary

The present work is the first trial on the effects of physical exercise in resistant hypertension. It shows that exercise is a helpful adjunct to control blood pressure in this setting.
Postexercise hypotension after Resistance Exercise in elderly

<table>
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<tr>
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<th>S2</th>
<th>S3</th>
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<td>DBP (mmHg)</td>
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<td>MBP (mmHg)</td>
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<td>HR (bpm)</td>
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<td>HIP (ml/kg/min)</td>
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Data are presented as mean ± standard deviation; Kg - kilogram; m² - meters squared; BMI, body mass index; mg/dL- milligrams per deciliter; ng/dL- nanograms per deciliter; HDL, high-density lipoprotein; LDL, low-density lipoprotein; IACE, inhibitor of angiotensin converting enzyme, SBP, systolic blood pressure; DBP, diastolic blood pressure; mmHg - millimeters of mercury; HR, heart rate; bpm - beats per minute; LF- Low frequency; HF- High frequency; LF/HF- Autonomic balance; FBF, forearm blood flow; HIP - Hyperemia.

**Figure 1**

**Figure 1**: Experimental protocol divided into three stages (pre-intervention, intervention and post-intervention). Inst, instrumentation; BP, Blood Pressure; ECG, electrocardiogram; FBF, Forearm Blood Flow; Ocl, Oclusion; B, Breath.

**Figure 2**

Figure 2: Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Mean Blood Pressure (MBP) at Control and post exercise. Data are presented as mean and standard deviation. * p<0.05 vs. rest, # p<0.05 vs. Control † p<0.05 vs. S1.
Figure 3

Figure 3: HR response and spectral components of LF, HF and LF/HF in Control and post exercise (S1 and S3). Data are presented as mean and standard deviation. * p< 0.05 vs. rest, # p< 0.05 vs. Control † p< 0.05 vs. S1.

Figure 4

Figure 4: Forearm Blood Flow in Control, S1 and S3. Data are presented as mean and standard deviation. * p< 0.05 vs. rest, # p< 0.05 vs. Control † p< 0.05 vs. S1.

Figure 5

Figure 5: Reactive hyperemia response in Control Session (CS), S1 and S3. Data are presented as mean and standard deviation. * p< 0.05 vs. rest, # p< 0.05 vs. control † p< 0.05 vs. S1.
### Figure 1

**Pre-Intervention**

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**Intervention**

- Session of Exercise
  - S1
  - S3
- Control Session

**Post-Intervention**

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Figure 3

![Graphs showing heart rate, low frequency, high frequency, and LF/HF ratios over time for different sessions.](image-url)
Figure 4
Figure 5

Hyperemia

- Pre-Intervention
- Post-Intervention

Hyperemia

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