Studying Upper and Lower Extremities Bioimpedance during Lower Body Negative Pressure induced hypovolemia

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Background: Lower body negative pressure (LBNP) is an experimental model for studying the physiologic change of hypovolemia, as -30, -60, and -90 mmHg LBNP approximate average blood losses of 450, 1000, and 1600 mL respectively in a 70 kg human[1,2]. LBNP reduces venous return by sequestrating blood into the lower parts of the body. This leads to rapidly decrease in central blood volume resulting in increasing in heart rate and vasoconstriction, so systemic vascular resistance increases[3]. The Bioelectrical Impedance Analysis (BIA) is based on measurement of electrical impedance (Ω) of a whole body or particular body part estimated by measuring the voltage signal developed across that body part by injecting a constant current signal. As the blood represents the most electrically conductive substance in the body, the blood volume changes can be detected by the impedance measurement of the particular body part. From the electrical current aspect, the blood volume is considered as an extracellular fluid, so the low frequencies (5KHz or less) are recommended for the measurement.[4] The objective of this study is to demonstrate the changes in upper and lower extremities bioimpedance during LBNP-induced hypovolemia and if valid, BIA can be used as a tool to improve the clinical management of volume status during hemorrhage and resuscitation.

Methods: With IRB approval, this study included 14 healthy volunteers underwent gradual LBNP which is consisted of 3-minute at baseline, -15 mmHg, -30 mmHg, -45 mmHg, -60mmHg, recovery at -30 mmHg and recovery at baseline. We connect the Bodystat® Multiscan 5000 (Figure 1-A) to the electrodes that were placed over the right foot and upper part of the leg, the right hand and upper part of the arm as shown in Figure 1-B. We measured bioimpedance at each phase of LBNP and the values were recorded. Data reported as mean (SD), the changes of bioimpedance from both sites from baseline were calculated using student's t-test, P value<0.05 was considered significant. Correlation between changes in leg, arm bioimpedance and estimated blood loss from LBNP was calculated using Pearson correlation.

Results: A total of 14 healthy volunteers were enrolled. one volunteer was excluded because of incomplete data. 13 subjects were in the final of analysis. As we progress in LBNP-induced hypovolemia there was significant increase in the arm bioimpedance and an associated decrease in the leg bioimpedance as shown in Figure 1-C. During recovery -30 phase (where blood is shifted from the leg to the body), there were an increase in leg bioimpedance and a reduction of arm bioimpedance. During Recovery baseline phase, (Figure 1-D) the leg continued to increase while the arm bioimpedance showed significant increase as a result of shift of metabolites from leg to the body resulting in vasodilation and shifting of blood from the arm to the body. The correlation between estimated blood loss and arm bioimpedance (r=0.93) and leg bioimpedance (r=-0.82) as shown in (Figure 1-E and 1-F) respectively.

Conclusion: Using LBNP-induced hypovolemia is effective model for studying the changes in bioimpedance of the extremities during hypovolemia and resuscitation. during. During LBNP, blood sequestration in the leg is associated with decrease in leg bioimpedance while the arm bioimpedance will progressively increase and the reverse happened with recovery. The changes in arm bioimpedance could also give insight about vasoconstriction and increase systemic vascular resistance during hypovolemia.

References:

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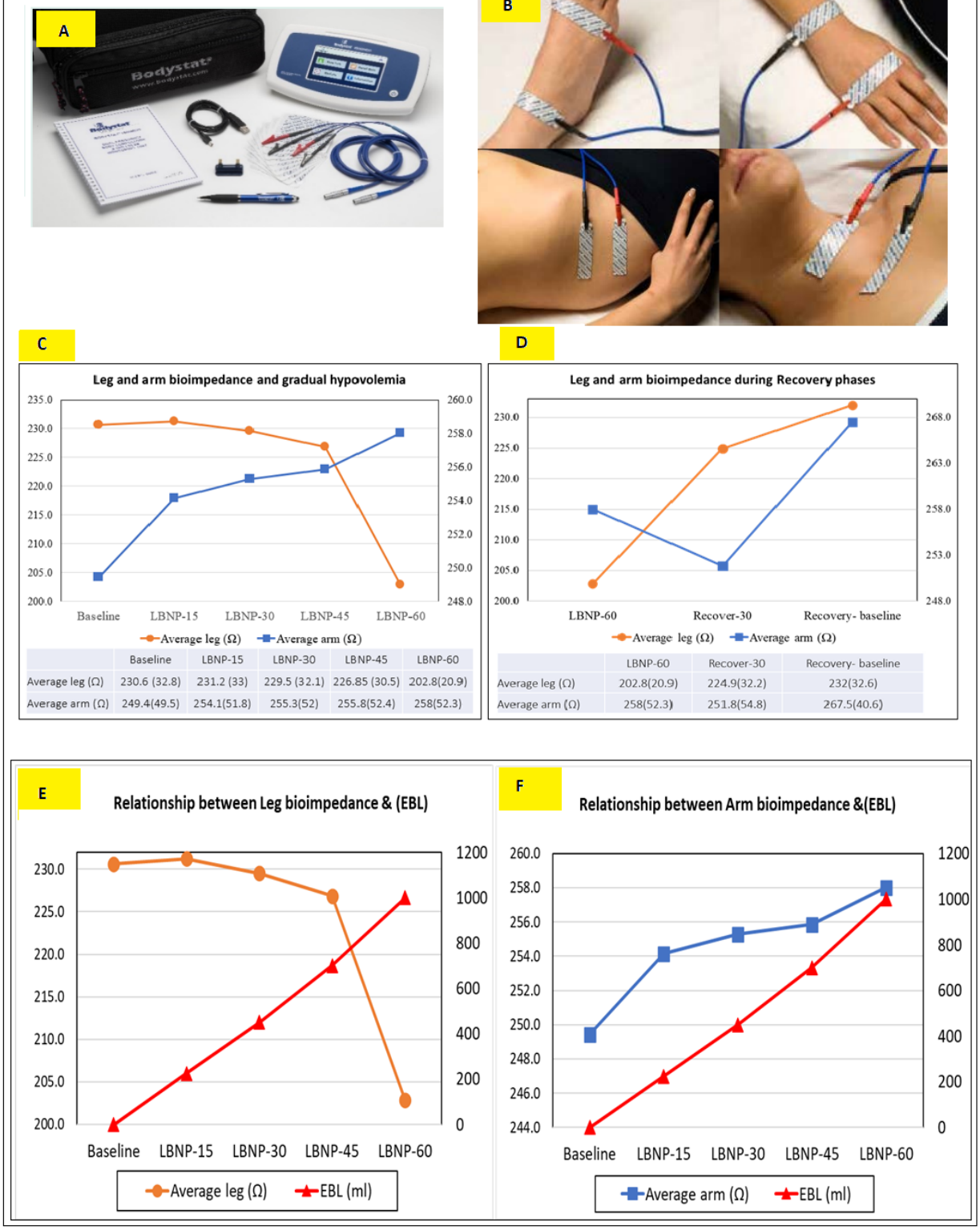

	Baseline	LBNP-15	LBNP-30	LBNP-45	LBNP-60
Average leg (Ω)	230.6 (32.8)	231.2 (33)	229.5 (32.1)	226.85 (30.5)	202.8(20.9)
Average arm (Ω)	249.4(49.5)	254.1(51.8)	255.3(52)	255.8(52.4)	258(52.3)

	LBNP-60	Recover-30	Recovery- baseline
Average leg (Ω)	202.8(20.9)	224.9(32.2)	232(32.6)
Average arm (Ω)	258(52.3)	251.8(54.8)	267.5(40.6)

Figure1: A: Bodystat® Multiscan 5000, B: Electrodes placement, C: Leg and arm bioimpedance during gradual hypovolemia, D: Leg and arm bioimpedance during recovery phases, E: Relationship between leg bioimpedance and Estimated blood loss (EBL) F: Relationship between arm bioimpedance and Estimated blood loss (EBL)